AGARD-AR-288

AGARD-AR-288

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

AGARD ADVISORY REPORT No.288

Workshop on Low Level Flight Training

(Groupe de Travail sur l'Entraînement au Vol à Basse Altitude)

NORTH ATLANTIC TREATY ORGANIZATION

DISTRIBUTION AND AVAILABILITY
ON BACK COVER

AGARD-AR-288

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.288

Workshop on Low Level Flight Training

(Groupe de Travail sur l'Entraînement au Vol à Basse Altitude)

This Workshop took place, 23rd—27th October 1989, at IABG, Ottobrunn, Federal Republic of Germany.

The Mission of AGARD

According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

– Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;

– Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);

– Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

– Improving the co-operation among member nations in aerospace research and development;

– Exchange of scientific and technical information;

– Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

– Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The content of this publication has been reproduced directly from material supplied by AGARD or the authors.

Published June 1990

ISBN 92-835-0572-7

Printed by Specialised Printing Services Limited
40 Chigwell Lane, Loughton, Essex IG10 3TZ

Preface

In March 1989 the national delegates board asked the AGARD panel chairmen to discuss with their respective panels whether they could contribute to a solution to problems posed by Low Level Military Flight Training. In May 1989 the military committee sent a Formal Request (IMSWM DFG-56-89) asking AGARD to sponsor a workshop to address the problem. Previous discussions about such a workshop led to the idea that the AASC might sponsor the workshop and include in it representatives from interested AGARD panels. At their meeting on 5th–7th June the AASC agreed to sponsor such a workshop on Flight Training Simulation, with Germany providing the Chairman, and asked the AGARD Director to propose the plan to the steering committee and the NDB.

The workshop took place, 23rd–27th October 1989, at IABG, Ottobrunn, Federal Republic of Germany.

Préface

Au mois de mars 1989, le Conseil des Délégués Nationaux de l'AGARD a demandé aux Présidents de Panel de l'AGARD d'interroger les membres de leurs Panels respectifs sur leurs contributions éventuelles à la résolution des problèmes posés par l'entraînement militaire au vol à basse altitude.

Au mois de mai 1989, le Comité Militaire a présenté une demande officielle (IMSWM DFG-56-89) demandant à l'AGARD de créer un groupe de travail pour étudier ce sujet.

De certaines discussions antérieures est née l'idée que l'AASC pourrait parrainer un tel groupe, en y invitant des représentants des Panels intéressés. Ainsi, lors de la réunion de l'AASC du 5 au 7 juin le comité a approuvé le patronage d'un groupe de travail sur la simulation de l'entraînement au vol, dont la RFA a été chargé d'assurer la présidence, et il a demandé au Directeur de l'AGARD de soumettre le projet au comité directeur de l'AASC et au NDB.

Le groupe de travail s'est réuni du 23 au 27 octobre 1989 à l'IABG, Ottobrunn, République Fédérale Allemagne.

Aerospace Application Study Committee

Chairman: Ing. Gén A.Queinec

WORKSHOP ORGANISATION

Chairman: Rolf Behrmann
Projectmanager
IABG/WTZ
Einsteinstraße 20
8012 Ottobrunn
Federal Republic of Germany

Secretary: Wg Cdr Ian Strachan
Operational Requirement 10 (Air)
Ministry of Defence
Whitehall
London SW1A 2HB
United Kingdom

Subgroup 1
Operational Aspects
Subgroup Leader
Rolf Behrmann
Projectmanager
IABG/WTZ
Einsteinstraße 20
8012 Ottobrunn
West Germany

Subgroup 2
Technical Aspects
Subgroup Leader
Rolf Lautenschlager
Dipl.-Ing. (FH)
IABG/WTS
Einsteinstraße 20
8012 Ottobrunn
West Germany

List of Participants

NO.	NAME	ORGANISATION	SUP-GROUP
1	Balke, H. - J.	BWB, LG I 3, Ge	1
2	Banks, C.	MoD, UK	1
3	Barrette, R.E.	CAE, Canada	2
4	Behrmann, Rolf	IABG, Ge	1
5	Cacciatore, Giulio	AIR STAFF ROME Stato, Maggiore Aeronaut., It.	1
6	Castle, Skip	DCSOPS/AVUA-SEB, USA	1
7	Castoldi, Paolo	AIRITALIA, Italia	2
8	Civeli, Luca	Aermacchi, Italia	2
9	Hunt, Darrel	USAFE/DOQ, USA	1
10	D'Ayguevives, Emmanuel	Thomson CSF, France	2
11	Fuchs, Werner	Dornier, Ge	2
12	Goddery, P.J.M.	Ministrie van Defensie, NL	1
13	*Guicheteau, Philippe*	*Onera, France*	2
14	Hanke, Dietrich	DLR, Ge	2
15	Heffernan, Robert	AF/XOOTT, USA	1
16	Heyboer, S.	Minstrie van Defensie, NL	1
17	Holthusen, Helmut	BWB, FE I 4, Ge	2
18	Huckins, Nigel	MoD, UK	1
19	*Illauer, Dieter*	LwRüst, Ge	1
20	Keppeler, Dirk	MBB,Ge	2
21	Lautenschlager, Rolf	IABG, Ge	2
22	Laven, Brian M.	Rediffusion Sim. Ltd., UK	2
23	Leonard, P.	BE. AIRSTAFF, VS3/TAC Force Aerienne, Belgium	1
24	Lotz, Peter	BMVg, Ge	1
25	Lynch, Brian J.	Singer Link-Miles Ltd., UK	2
26	Merkel, Hubert	LwA, Ge	
27	Müllner, Josef	Evans & Sutherland, Ge	2
28	Murray, Paul	Rediffusion Sim. Ltd., UK	2
29	Perrotte, F.	NATO HQ, Belgium	2
30	Redmond, T.W.	AGARD, France	1
31	Robbins, D.K.	Canada	1
32	Schreiber, Rolf	BMVg, Rü IV 1, Ge	1
33	Shilen, J.	CAE, Canada	2
34	Strachan, Ian	MoD, UK	2
35	Tuck, Chris	SHAPE, Belgium	1
36	Ugurluoglu, Orhan	Turkey	1
37	Vermeulen, Wim G.	NLR, NL	2
38	Welsch, Heiko	FLMED Inst. Manching, Ge	1
39	Woodfield, Alan	Roy. Aircraft Est., UK	2
40	Onken, Reiner	Univ. d. Bw., München	2

Contents

List of Annexes

1. Executive Summary of Conclusions

1. General. The workshop could offer no recommendation for reducing the present levels of fast-jet low flying. It was concluded that the present trend of restrictions on low flying training might already be having an adverse effect on combat readiness. To overcome these effects, it was recognised that improvements in the total training concept were necessary, to include both live flying and synthetic training.

2. Live Flying. To compensate for the reduction in operational training due to low flying restrictions, a need was identified for training facilities capable of providing more realistic tactical combat training. The appropriate NATO agency is strongly urged to continue to pursue the creation of further instrumented tactical ranges.

3. Synthetic Training.

a. The workshop analysed the potential for synthetic training, considering training devices ranging from specialised Part-Task-Trainers to the Full Mission Simulator.

b. Various deficiencies were noted in current state-of- the-art technology in fulfilling the low-level tactical role over the required large geographic areas. Although some of these deficiencies were being addressed by industry, it appeared that some of the critical deficiencies might take several years to resolve.

c. More information was needed on what was required for low-level synthetic training. The FRG and UK will soon have facilities which might allow evaluation of some of the important factors related to low level simulation. The workshop supported the use of these and any other facilities that would provide additional information on meeting operational training requirements for low level flying.

d. However, simulation technology was now capable of providing limited training in some activities which cannot be flown in aircraft during peacetime. These include technology to simulate operations in geographic areas which are prohibited to aircraft, in threat and electronic warfare conditions, with unrestricted release of weapons. Visual scenes are at present stylised, but can be based on real world terrain and features for the purpose of mission rehearsal.

e. Various recommendations were made with a view to improving the data available for combat simulation, and to proposing standards for various aspects of simulation. These recommendations appear in the detailed reports which are attached.

1.1 Detailed Summary of Recommendations and Conclusions (Technical Subgroup)

The following general recommendations appeared in the proceedings of the Technical Group, and are grouped into subjects below.

RECOMMENDATION	REF.*	ACTION
DATA		
1. Data which will be required for simulators should be part of the contract for the main aircraft or equipment programme, so that when the simulator contractor(s) need it, it will be available.	Paras 1	Nation's Operational Requirements and Procurement staffs to specify that simulator data packs will be provided by the aircraft and equipment manufacturers.
2. NATO standards for data are required, similar to those in use by the FAA, IATA, etc.	33	An agency knowledgeable in military simulation to be asked to draft such standards should take into account the various military roles.
3. A NATO agency is needed for collation of data base information to avoid duplication of effort between nations and manufacturers. Visual, radar, EW and IR information should be included, and co-ordination should be ensured with USAF Project 2851.	19	AGARD National Delegates Board to pass this recommendation to the MC. Project 2851 participants to note
Information such as the position of fixed emitter sites, SAM/AAA, potential targets etc, should be included. Such data should include: a. DMA/DMLS digitised mapping information, both DTED and DFAD, and data from any successor systems. b. Satellite data (Such as SPOT). c. Air Reconnaissance Photography. d. Ground Photography. e. Paper Maps. f. Radar imagery at various frequencies. g. IR imagery		

* Ref. paras out of the proceedings of the technical report.

RECOMMENDATION	REF.*	ACTION
h. Emitter data, fixed & mobile		
j. Any other data sources, eg tourists, agents etc.		
4. Data from aircraft Flight Data Recorders should be capable of being used in Simulators, both to update the simulator data base where an incident occurs outside the aircraft tested flight envelope, and also to replicate the incident for analysis and training.	32	National Operational Requirements and Procurement staff to note. Industry to note (Aircraft, Flight Data Recorder and Simulator contractors).
5. Data is needed on limiting parts of the flight envelope (such as for departures where post stall effects are to be modelled).	1 a	Customer to ensure that such data is available to simulator manufacturer. As Serial 1.
<u>STANDARDS</u>		
6. Aircraft hardware and software that may be required in simulators should be compatible with direct use in simulators without modification, in a similar way to equipment for civil aircraft designed to the provisions of ARINC 610.	2, 31	A NATO STANAG is required, paralleling the civil ARINC 610. Nations to specify the need for interchangeable boxes in operational requirements and procurement specifications.
7. NATO operating and technical simulator standards be drawn up for different levels of simulator operation, in a similar way to FAA Phase 1, 2 and 3 standards.	23	As the action to Serial 2
8. Standards and format of data for simulators to conform to a NATO standard in a similar way to FAA, CAA and IATA data standards.	33	As Serial 2 action.
9. Simulator interfaces for linking or networking with other simulations to be to a common standard in order to ensure compatibility if networking is required.	35 a	As Serial 2 action.

* Ref. paras out of the proceedings of the technical report.

RECOMMENDATION	REF.*	ACTION
RESEARCH		
10. The FRG to use its simulation facilities, particularly its programme using the CAE Fibre-Optic Helmet Mounted Display, and the ESIG-1000 Image Generator, motion platforms, G Seats etc as appropriate, to evaluate visual and other cues necessary for training for the low level task.	21 a 4 a 5 a 11 21 c 24 e	FRG to evaluate simulation cues needed for low level and other combat training and produce report for the AGARD FMP and for general circulation. Co-coordinated with similar UK programme at Serial 9, and noting the US Army SCTP programme.
11. UK evaluation similar to Serial 10, particularly using the RAE facilities at Bedford, and the Harrier GR 5 Mission simulators using the ESPRIT eye-slaved display system, the MOD DIG Image Generator, 6 DOF motion platform, and G seat.	21 b 4 a 5 a 11 21 c 24 e	UK evaluation and report as Serial 8 above, co-ordinated with FRG programme, and noting US Army work.
12. Other Nations were invited to use their simulation facilities for studies similar to the UK and FRG programmes in Serials 10 and 11.	21 c	National Research agencies to note, and coordinate with FRG and UK programmes.
13. Research needed on crew behaviour in a low level and combat environment, such as on visual scan patterns, head movements activities in various tasks, reaction to various cues, etc.	21 d	National Research agencies study and report.
14. Research needed on the technology, capabilities and limitations of network links, related to the various roles to be trained.	35 b	National Research Agencies and Industry to study and report.
EQUIPMENT		
Visual Systems		
15. Field of View (FOV).		
Total FOV close to that of the aircraft is desirable.	4	Nations and Industry to note.
Total FOV of less than about 140 horizontally by 70 vertically is unlikely to prove suitable for simulation of low flying.	4	Nations and Industry to note.
16. Virtual Image Displays (Coll.) Virtual image displays (Collimation) with wide horizontal angles, as used in airline simulations, were not as important for combat simulation as providing the FOV required (see Serial 15 for FOV).	4 a	Nations to note. VFOV for combat simulation appears to be the critical design factor. See Serial 15 above.

* Ref. paras out of the proceedings of the technical report.

RECOMMENDATION	REF.*	ACTION
17. <u>Resolution.</u> The minimum resolution for viable simulation of the Air-to-Ground role is 4 arc minutes per Optical Line Pair (2 mins per pixel) or better, in the foveal vision.	5	Nations and Industry to note.
18. <u>Image Brightness.</u> The target for future military simulators should be 10 foot-Lamberts, compared to the current civil requirement of 6 foot-Lamberts.	6	Nations and Industry to note.
19. <u>Stereoscopic Imagery.</u> For fast-jet low level simulator training, stereoscopic imagery was not considered to be required.	14	Nations and Industry to note.
20. <u>Realistic Weather Effects.</u> Realistic weather effects related to the low flying environment were not yet fully available, and were a requirement.	15	Nations to note, and to specify realistic weather effects in future simulator procurements. Industry to increase system capabilities.
<u>Data Base Work Stations.</u>		
21. There was a need for powerful, user-friendly Data Base Work Stations for Military simulators, so that complex data bases (Visual, IR, Radar, Threat, EW etc) could be created, and adjusted and optimised in Service.	13	Nations to note. Industry to increase DBWS capabilities.
<u>Motion Cueing.</u>		
22. <u>Poor Motion Cueing.</u> Poorly set-up motion platforms, and some older motion platforms, particularly with high latencies, were agreed to have produced adverse effects.	24 a 24 b	Nations to note.
23. <u>Modern Motion Platforms.</u> Modern synergistic motion platforms using smoothly operating hydrostatic jacks, well set-up for the aircraft and role, were very beneficial to realistic training and to the use of real aircraft control and stability models in the simulator.	24 c	Nations' Operational Requirements and Procurement staffs to note.

* Ref. paras out of the proceedings of the technical report.

RECOMMENDATION	REF.*	ACTION
24. Handling Qualities. It was likely that handling qualities became less realistic if a well-set up motion platform was not used.	24 d	As Serial 23 above.
25. Time Delays - Latency. The target latency (platform reaction time) for fighter aircraft simulators, should be 100 msec (as in US MIL STD 85 C for fighter aircraft).	25	As Serial 23. Industry to note and improve performance from the present standard of about 120 msec.
26. Time Delays - Motion Platform and Visual System. Motion responses must be felt by the simulator pilot before visual system responses, or disorientation can result.	9, 24	Nations and Industry to note.
27. Simulator Sickness. Pilots operating with wide FOV visual systems with rich scene detail, without well set-up motion platform cues, showed a tendency towards various symptoms of Simulator Sickness. This tendency was reduced with cues from a good standard of modern motion platform.	29	Nations and Industry to note.
28. Instrument Flying (IF) Where a good standard of modern motion platform was used, simulator training for IF could be very realistic, shown by the fact that the better standard of civil simulators with modern motion platforms were used to gain "credits" for IF. It was suggested that any aircraft time saved should be used for more combat-related tasks.	27	Nations to note
Sensor Simulation		
29. Sensor data available to the simulator manufacturers to be improved.		
a. Data on the characteristics of the individual sensor.	33	As actions for Serials 1 and 2.
b. Data in the particular frequency spectrum (ie Radar, IR etc) from the real world.	19 f 19 g 19 h	NATO co-ordination needed to avoid duplication of effort between nations and within industry.

* Ref. paras out of the proceedings of the technical report.

RECOMMENDATION	REF.*	ACTION
30. Radar processors in simulators to be programmable so that optimisation to real radar responses can be carried out, and changes due to modifications to the aircraft radar be achieved without difficulties.	16	Nations and Industry to note.
31. IR processors in simulators to be programmable for the reasons given above in Serial 30.	17	Nations and Industry to note.

1.2 Detailed Summary of Recommendations and Conclusions (Operational Subgroup)

The following general recommendations appeared in the proceedings of the Operational Group and are grouped into subjects below.

RECOMMENDATION	ACTION
1. General	
Investigate the increase in training effectivenes by introducing more full interactive crew stations to be able to fly and train composite force operations (wargaming) in the simulator.	AGARD to note Airstaffs to note
Investigate the technical ablity and show the limitations and costs to internet A/A simulators at different airbases.	AGARD to note Airstaffs to note
2. Data base The data base was identified to be a major problem . By the feel of the workshop members NATO should work with a standardised data base.	AGARD to note Airstaffs to note
3. Different Cockpits Investigate the impact of different aircraft cockpits on the simulator design and define standardised interfaces.	AGARD to note Airstaffs to note Industry to note
4. Helicopter Simulation Further research is necessary to state the application or additional requirements for helicopters.	AGARD to note Airstaffs to note

2. Workshop Conduction

Introduction

AGARD is looking for solutions to solve problems posed by low level flight training. The AASC was tasked to sponsor a workshop on low level flight training simulations with Germany providing the chairman.

The workshop took place 23. - 27. Oct. 1989 at IABT, Ottobrunn, FRG.

* Ref. paras out of the proceedings of the technical report.

40 Experts from 9 NATO countries were participating the workshop:

Belgium
Canada
France
Germany
Italy
Netherlands
Turkey
United Kingdom
United States of America.

Objectives

Provide AGARD advise on weather flight simulation technology might help to resolve the problems assosiated with low level flight training, and suggest how AGARD should proceed in this area.

- Register existing requirements for low level flight training mission events in which flight simulator technology shows great potential.
- Identify ways that simulator technology can be applied to reduce undesirable impact of low level flight training.
- Investigate new training concepts that use alternave flight training connection with simulators to meet flight training requirements.
- Identify ways to measure the effectiveness of simulator training in meeting the operational training requirements.
- Suggest possible topics for follow-on technology studies or aerospace applications studies.

General

As a lead into the workshop theme BGen Merkel gave a presentation about the low level flight training situation within the german air force. In his presentation he pointed out the need for offensive air assets, discussed the anti-low-level-jetnoise movement within germany and described the consequences deriving out of these movements and measures taken, agreed with the Allies, to get an immediate and noticable noise relief of the population, e.g.:

- Low-flying aircraft will operate at reduced airspeed.
- Low-flying time is 75 m within particularly assigned low-level areas will be significantly reduced.
- The number of low-level flying hours will be reduced.

At longer terms, further reliefs are to be expected with noise export and simulation.

The Annex A-A-1 shows in the noise level time history the effect of an over-flight with an aircraft in 75 m, while A-A-2 points out the noise levels of different aircraft and speeds at a height of 75 m.

Workshop Outline

Following the opening words, agreement on the agenda (ANNEX A-A-3) was achieved and the workshop divided into an operational and technical subgroup.

Within these subgroups the following theme were discussed:

Subgroup 1 - operational aspects

- Flight training restrictions
- Deficiencies in training
- Mission analysis of a typical Air to Ground (A/G) mission

Result:

- Operational requirements for a simulator to overcome deficiencies in training
- AGARD advise for investigations and considervations.

Subgroup 2 - technical aspects

- visual systems
- data base
- motion systems

Result:

- Capabilities of low level training simulators today

- AGARD advise for investigations and considerations.

In the final discussion the complete workshop compared the operational requirements to the simulation capabilities and achieved agreement an the executive summary.

3. Report of the Operational Subgroup (1)

Subgroup Leader: Rolf Behrmann, FRG, (IABG)

Note: This is the summary of a long and highly motivated detailed discussion. The discussion was limited to the Fast Jet Training Aspect. The differences in requirements for a Helicopter and the Fast Jet Simulator can be reduced to different speed, to resolution and scene density (data base) requirements.

The discussion was limited strictly to the training aspect. Several Nations made quite clear that there will be no substitution live flying for simulator flying.

SUMMARY OF PROCEEDINGS

1. Flight Training Today.
Following the introduction of BGen Merkel the flight training over Germany is

influenced by the following factors:

a) Peace time flying regulations
   - restriction in low level flying time
   - speeds
   - minimum altitudes.

   All of these regulations have been changed in order to reduce the low level jet noise over W-Germany.

b) The training flights are not taking place in the assumed combat areas.

c) Training flights cannot be flown under realistic combat situations due to the missing ECM and threat scenario.

   The training of c) can only take place in specially assigned areas and is conducted only in a limited number of flights (Red Flag).

d) There are limited opportunities to qualify combat ready.

   The changes in low level flight regulations will increase the training gap between Combat Ready (CR) and Combat Capable (CC).

Definition of Combat Capable:

Combat Ready + Combat Experience = CC

A Mission Rehearsal Simulator (MRS) may reduce the training gap between CR und CC.

2. Operational Requirements of a MRS

The simulator should fill the training gap which is forming due to the changing low level flight regulations and be able to train mission events which cannot be flown under peace time conditions.

Overall considerations
The mission has to be conducted under the following overall considerations

- all weather situation
- in a realistic threat environment (A/A and G/A)
- over the real combat terrain
- day and night
- in tactical formation
- under peace- and wartime-conditions
- with all Nato aircraft
- deploy all weapons
- in the C_2 environment
- under NBC and electronic warfare conditions.

1. Weapon-delivery

- weapon-effectiveness and effects incl. safe escape manoeuver
- to reach delivery parameters
- to aquire and identify the target
  - o visual
    with fire coordination (FAC)
  - o sensors
    laser (own/outside)
    radar
    flir
    night vision goggles
    electro optics.

2. IP to target acquisition

- switchology
- tactical/delivery manoeuver
  leave the terrain masking
- change the navigational method
- IP identification
- timing

3. Ingress (start of the low level portion)

- systems considerations
- flight considerations
- speed
- airspace control (Airspace management in accordance with NATO procedures)
- survival
  - o masking
    terrain
    self protection ECM
    dedicated mission support
    mutual support.

4. Egress

- see point 3
- escape weapon effects.
- rejoin

5. Transition to ingress

- refuelling
- navigation
- airspace coordination considerations
- switchology
- package formation (multi forces e.g. Wild Weasel, Reccle, Escorts)
- threat/tgt update

6. Transition to recovery

- refuelling
- navigation
- airspace consideration (Airspace management)
- battle damage considerations
- switchology
- safe passage
- post mission reporting
- recovery considerations.
- diversion procedure

7. To / departure

- safe passage
- heavy weight considerations
- damaged runways
- switchology
- impaired system consideration
  (GO/NO GO)
- communication
- timing

8. Approach and landing

- safe passage
- damaged runways
- switchology
- battle damage considerations

9. Ground operations

- briefing / debriefing
- airfield configuration considerations
- air raid considerations
- mission preparation

Operational requirements on the mission rehearsal simulator

The mission tasks and considerations are converted into simulator requirements.

General requirements

- full coloured visual display
- aircraft type cockpit
- simulation of all aircraft systems
- simulation of total aircraft performance
- threat simulation (A/A, G/A)
  - o ECM interface
  - o Defences
    - Flares
    - Chaff
    - Endgame simulation
- Airspace management in accordance with NATO procedures and plans
- Growth potential
  - o A/C modification
  - o Weapon modification
  - o Threat modification
  - o tgt modification
- G cues
- accustic cues

Weapon-delivery

The simulator must be able to perform:

- calculations of ballistics and trajectories of all weapons incl. guidance and control with growth for future weapons

- calculation of the CEP of the delivered weapon

- simulation of weapon malfunctions

- simulation of weapon release cues

- calculation of fragilisation envelopes and simulation of fragilitsation effects on own A/C, following or preceeding A/C

indication of weapon-effects in the visual systems (blast, smoke)

- indication in the visual system of weapons release of forward firing weapons, flight path of forward firing weapon (own and threat) and change in aircraft configuration.

Target acquisition

Visual
- to see the target at the correct range in the correct size and shape under the lighting- and weather-conditions of the day/night and terrain restrictions. (The aircrew has to be able to identify the target.)

Target area
- high resolution. Refer to AGARD Advisory Report 159 (1979). The level of detail required for pilots acceptance and mission effectiveness has to be carefully assessed by operational aircrews.

NOTE
AGARD to advise

The data base was identified to be a major problem area.
By the feel of the workshop members NATO should work with a standardised data base.

Sensors
- all sensors must be simulated realistic and the data to be used for the sensors must be correlated. All influence factors (atmosphere) must be simulated.

Altitude
- realistic three-dimensional presentation of the geographical terrain base. The aircrew must be able to fly contour mapping

Speed
- full range of aircraft capabilities (incl. acc/dec).

Level of detail and scene density
- the whole data base incl. cultural features should have a level of detail like on a 1 : 50 000 map.

Emergencies
- a simulation of system malfunction and battle damage is required

Debriefing
- the simulator should fullfil the same briefing and debriefing tasks like in the ACMI. Simultaneous briefing/debriefing and simulator training must be possible.

No. of participants
- ideal is to fly the same kind of missions with the same number of participants like the training flights. A minimum of 2 full interactive crew stations are required.

- must be able to present A/A and A/G targets simultaneusly.

NOTE
AGARD to advise

The increase in training effectiveness by intrcducing more full interactive crew stations to be able to fly and train composite force operations (wargaming) in the simulator.

ADDITIONAL DISCUSSION

Motion System

During the discussion of the operational benefit of a simulator motion system it was clearly stated by all nations that flying cannot be duplicated-only be simulated.

Experience with the Dual Flight Simulator (DFS) at IABG and tests executed in UK indicate, that a motion system, which is compatible to the aircraft performance will increase the fidelity and riding qualities and is able to simulate certain weather effects like gusts and turbulence. It is also a factor in pilots acceptance. By the feel of the operational group a motion system is a requirement for modern simulators. The common discussion with the technical group showed that the costs of such a motion system will be only 5 - 10 % of the total simulator costs.

The motion system will have an impact on the infrastructure of the simulator. Outside dome projections are not possible in conjunction with the motion system.

Different Cockpits

The requirement for different and changable cockpits is complicating the simulator design.

NOTE

AGARD to investigate the impact on simulator design and define standardized interfaces.

Helicopter Simulation

Only the fast jet aspect of low level flying was discussed.
The differences to helicopter simulations are in following areas:

- lower speeds
- different resolution requirement
- different level of detail and scene density requirement
- different scenario.

NOTE

Further research is necessary to state the application or additional requirements for helicopters.

Formation Flying

The normal A/G mission will be flown with two or more participants. (The number of participants is variing due to different operation concepts within the nations.) In order to fly cooperative tactics the simulator needs at least 2 full interactive manned stations (type cockpits with visual systems).

NOTE

Investigation is needed to show the operational benefit of a simulation centre (more than 2 full interactive crew stations) including the costs. All simulators are internetted on the same base.

NOTE

Investigation is needed to show the technical ability to internet simulators at different bases, including costs.

Simulation Operation Station (instructor consoles)

The functional design must be such, that the simulations can be run by a minimum crew (1 technician and 1 instructor pilot).

Limitations of Simulators

1. No simulation of stress

o fear in real combat.

It was stated, that the stress level in simulators could be increased by increasing the workload. It was the feeling of the operational group, that an aircrew in the simulator may accept a higher workload - because he knows, that he is sitting in a simulator - than under the stress of a real combat situation.

2. Limitations in simulating G-Forces

In the simulator the aircrew does not encounter the real body fatigue like in live flying.

Training Philosophies

It was discussed that training is a combination of

- Academic Training
- Synthetic Training
  - o Part Task
  - o Mission Rehearsal Simulators
- Live Flying
  - o Training in the wings
  - o Training at ranges (weapon delivery, EW)
  - o combat training (Red Flag).

This training is producing a Combat Ready Aircrew (CR).
To be full Combat Capable (CC) the real combat experience is missing.

Substitution Live Training with Simulator Training

Any reduction in live flying and increase in simulator flying will not decrease the gap between CR and CC it will only increase the ability to fly the simulator (see simulator deficiencies).

4. Report of the Technical Subgroup (2)

RECORD OF PROCEEDINGS OF THE TECHNICAL GROUP

Subgroup Leader (SL): Rolf Lautenschlager, FRG (IABG)
Secretary : Wg Cdr Ian Strachan, UK, (MOD, OR(Air))

NOTE: This is a summary of a long and sometimes highly detailed discussion. Attached at Annex C are copies of visual aids presented by various members to the group. Vufoil C-1 shows the different points of discussion (numbers offer to the paragraphs).

SUMMARY OF PROCEEDINGS	**RECOMMENDATION AND ACTIONS**
1. Aircraft data. There was a need for accurate data on aircraft and air systems to be provided to simulator manufacturers for the purpose of accurate modelling. Current standards of data for military simulation were not good and in many cases, poor. See vufoil C-2	MAIN RECOMMENDATION (Improved Data required)
a. Industry asked about the need for data on departure (Post-stall) conditions. The inference was that this data was often poor, and if a customer wished limiting parts of the flight envelope to be simulated, appropriate data had to be obtained and given to the simulator manufacturer.	Nations to Note
2. Avionic/EW systems. Where the use of real aircraft hardware was the best option for simulating a particular equipment, a military equivalent to the civil ARINC 610 was needed, to ensure that the hardware was designed for use in the simulator without the need for costly modifications.	MAIN RECOMMENDATION (Need for NATO equivalent to the civil ARINC 610)
3. Subjects for Discussion. The Subgroup Leader proposed that discussion should be organised in the subject groups shown on his vufoil which is reproduced at Annex C on page C-3. The first subject was Image Presentation (Visual Display Systems). See SL's vufoil C-4.	
IMAGE PRESENTATION SYSTEMS (Visual Display Systems).	
4. Field of View (FOV). Compared to the civil requirement, good vertical FOV was required for fast-jet simulation. It was agreed that a total available FOV close to that of the aircraft was desirable, but less that about 140° x 70° was unlikely to prove suitable for effective simulation of low level flying.	Nations and Industry to note.
a. The use of wide angle virtual image displays as used for airline simulation (such as WIDE, AWARDS, MULTIVIEW, focussed at or close to infinity (collimation)) was not considered as important for combat simulation as the FOV requirement above. Collimated imagery was therefore not considered essential.	Nations to note

b. Since the 'WIDE' types of display systems currently marketed have a maximum Vertical FOV of about 40°, to achieve the 70° or more VFOV required for fast-jet simulation would need either a Helmet Mounted Display (Such as the CAE Fibre Optic Helmet Mounted Display or FOHMD), an array of Collimated TV Monitors, or the use of direct screen projection ('real image'). One delegate suggested that because real imagery was at a closer focal length than the scenes that it was displaying, long exposure might cause eye strain. After discussion, it appeared that there was no experimental evidence on this subject, and since many simulators existed using real image techniques, it was important that the issue of possible eye strain be addressed and reported. — National Research Agencies to evaluate and report.

5. Resolution. The minimum standard of resolution for viable air-to-ground simulation was suggested as 4 arc minutes per Optical Line Pair (2 arc minutes per pixel) or better, in the pilot's foveal vision (centre of look). It was noted that the resolution of the centre of the human fovea was about 1 arc min/OLP. — Nations and Industry to note.

a. Air-to-air target detection and recognition was noted as a problem area, because targets in the real world were very small at the maximum range for visual detection, and still subtended small angles to the crew at ranges where the aircraft type could be recognised. In a simulator, maintenance of realistic detection and recognition ranges (an essential training requirement) needed either systems of higher resolution than 4 arc min/OLP, or the use of artificially enhanced targets to achieve the recognition and detection ranges required. Research was required on whether target enhancement (size, shape etc) at longer ranges had any adverse effects on the crew, such as being unreal enough to inhibit training effectiveness. See also paras 20 and 21. — National Research Agencies to study and report.

b. One solution, used in various air combat simulators, was to use separate target projectors instead of an overall CGI display. Laser projectors could also be used and gave very fine target resolution and detail. — Nations and Industry to note.

6. Image Brightness (Luminance). The civil requirement for daylight imagery was 6 foot lamberts (ftL). A target for future military simulators was about 10 ftL.

7. AOI-systems for WFOV. (Vuf.C-5) Because of the need for pilots to look off the head axis, eye trackers were desirable in wide FOV systems, to avoid expensive high resolution image generation in areas where the pilot was not looking. Head or Helmet tracking had also to be used so that the visual system computer could know

in which direction to generate the high resolution Area-of-Interest (AOI) display, and the lower resolution background display which was needed to cover the rest of the pilot's Instantaneous FOV. Several eye and head-slaved systems exist, some of which have been evaluated or have been ordered by Service customers. Details can be obtained from the various manufacturers, and both FRG and the UK had ordered such systems for the fast jet low level training role. It was stated that the use of these systems involved calibrating the eye-scan characteristics of user pilots and recording such calibrations for the purpose of setting up the system for subsequent simulator sorties. Initial calibrations were said to take about 20 or 30 minutes, and the setting up before subsequent sorties, between 2 and 5 mins. The UK reported results from their Harrier GR 5 simulator evaluation, which showed that in the low level ground-attack role, pilots frequently looked 30 off the head axis, and sometimes to the pilot's geometric limit (about 45 , depending on the individual's head and eye geometry). It was stated that, in the air, pilots were reluctant to use large head movements when under 'G', and so tended to use eye-scanning instead.

IMAGE GENERATION (IG) SYSTEMS

8. General. The information in the SL's vufoils at page C-6, C-7, C-8 was generally accepted with comments which are in the following paragraphs. — Nations and Industry to note.

9. Latencies of IG Systems. System latency was the time delay or reaction time taken to create a change to the visual scene. In discussion it was pointed out that the human body feels motion accelerations first, followed by the eyes detecting changes to the visual scene once the acceleration has built up sufficiently to produce a discernible displacement. Motion cues were therefore generally acceleration-related and visual cues were displacement-related. The inference for simulation was that motion platform movements must be felt by pilots before changes to the visual scene, or the brain would detect an unnatural sequence of cues, which was stated to lead to symptoms of simulator sickness such as disorientation (see also 29.).

10. Resolution of IG Systems. Several systems were available with a greater capacity than 512 Kpixels, 1000 x 1000 pixels being available from some systems. — National Research Agencies.

11. IG System Update and Refresh Rates. It was stated as desirable to have a high update rate for high speed low flying and rapid manoeuvring, to avoid intrusive image stepping. Industry pointed out that higher brightness would also increase the rate needed, if flicker was to be avoided. There was a trade-off between scene detail and update rate, doubling the Update rate approximately halving the scene detail. The UK stated that they recommended at least a 25 Hz update rate for real-time flight simulation, but various delegates suggested that this would be too low

for high speed, high manoeuvre combat tasks. In response, UK stated that 25 Hz was the minimum recommended figure for simpler tasks such as for training and transport aircraft simulation, but that there was a danger of losing the scene detail necessary for some tasks if high Update rates were pursued to the exclusion of other factors. Research was needed to establish the impact of update rates and scene detail on various low flying mission tasks. Industry pointed out that Update and Refresh rates must be compatible.

12. AOI Aspects. This referred to the eye-and head-slaved high resolution Area-Of-Interest systems covered earlier at para 7. See the SL's vufoil on page C - 9.
In discussion it was stated that square or rectangular shapes for the AOI display were visually obtrusive to the pilot, because the human eye characteristic of change of resolution with angle off the fovea was essentially circular. The UK stated that they had looked at various circular AOI angles varying from 6° to 30°, and for their Harrier GR 5 simulators had chosen a figure of 16° (+/- 8°) for the high resolution channel. This would be re-assessed shortly as part of acceptance testing on these simulators. The high angle rates of head and eye movement that could be made by pilots, were discussed. Fortunately for the design of simulator systems, there was a phenomenon known as Saccadic Suppression, whereby the brain did not process visual imagery during rapid eye movements, but waited until there was a steady, unblurred image available before registering it.

13. Data Base Work Stations(DBWS). User friendliness was a requirement. The UK stated that it would use junior NCOs of a new trade group for database work. Others suggested the benefits of contractor operators. There was a need for SECRET war route scenarios to be developed using the DBWS. Industry suggested there was a need for powerful, user-friendly DBWS, which were not yet available on the market. It was agreed that this was a serious problem that needed action.

Industry to produce powerful, use-friendly DBWS for future systems

14. Stereoscopic Effects. It was stated that some research has been done into presenting stereoscopic imagery to the pilot. Some tasks showed improvement but it was pointed out that a second high quality IG channel was needed, and some changes to the way objects were modelled in the visual database. For instance, in some IG systems, trees and other objects were modelled as flat surfaces at right angles to the pilot's angle of look; such objects had no sides or backs, but this was not discernible to the pilot because the orientation of the flat surface of the object changed in response to changes in his look-angle. With stereoscopic imagery this technique would have to be modified because a certain amount of three-dimensional information would have to be provided in the data base. It was agreed not to pursue stereoscopic imagery for low level training, although it might have a place in research, or other areas of training such as helicopters hovering close to vertical objects.

Nations and industry to note.

15. Weather effects. See SL's Vufoil C-12 There was a lack in present CGI systems of features such as broken cloud layers, finer steps of cloudbase, modelling from above holes in cloud layers with realistic terrain for descent to low level, and similar effects optimised for the tactical environment in Europe. Low flying weather deterioration effects in a European environment were needed. Industry suggested that these aspects were being addressed by IG manufacturers and should be available in the next generation of CGI systems. It was suggested that piecemeal simulation of events such as microbursts was often artificial. Better integration of weather effects to the sortie plan was needed. Wind and turbulence in low flying in hills must be modelled, as it had a significant effect on aircraft handling, and turning performance with respect to ground features (wind drift). Advice was sought by industry on weather effects needed for the European low level environment.

Industry to improve weather effects in future systems.

SENSOR SIMULATION

16. Radar Simulation. The points on the SL's vufoil at page C-11 were generally accepted. There was a need for the radar processor in the simulator to be programmable so that the simulated radar could be adjusted to be as close as possible to the real aircraft display, and also in order to be able to adjust the simulator radar display in response to modifications to the aircraft radar. It was suggested that adjustments might be achieved through a combined DBWS facility.

Nations to Specify.

17. Infra Red Simulation. The points on the SL's vufoil at page C-12 were generally accepted, with the qualification that a separate eye-point for the sensor position on the aircraft, may not be critical in the case of fast-jets, but might be for simulations of Attack Helicopters. It was suggested that IR modelling for simulation was in its infancy and needed work, which should be based on real-world IR imagery from operational sensors. It was also suggested that the IR processor in the simulator should be programmable in the same way as the radar processor in para 10 above. Faults specific to the particular system should be simulated, such as the effect of failure of a detector or detectors within the overall matrix of detectors, and imagery should be adjustable through the IR processor in order to closely match the display from the aircraft system. This should be able to produce such IR effects as cold-pooling before dawn, and low contrast in snow and rain. A combined DBWS facility might be used for such adjustments.

Nations and Industry to note.

VISUAL AND SENSOR DATA BASES

18. General. The points on the SL's vufoils on pages C-13 - C-17 were generally agreed. The following subjects were also covered.

Nations and Industry to note.

19. Data Acquisition and Collation. An urgent need was seen for a NATO agency to coordinate the acquisition and collation of data base information, with a view to supplying it to Nations and contractors to avoid duplication of effort in data base creation. Such a data base would have other military uses such as for Aircraft Mission Planning Systems, Army Battlefield Management Systems, Intelligence Agencies etc. It was suggested that the following source information should be collated:

MAIN RECOMMENDATION (Coordination of data base information at a NATO level)

a. DMA/DLMS levels 1, 2 and successor systems; see also page C-13.

b. Satellite data such as SPOT; see also page C-13.

c. Aerial reconnaissance photography.

d. Ground photography.

e. Paper maps, where relevant.

f. Radar imagery in the various parts of the frequency spectrum.

g. IR imagery.

h. Emitter data for fixed and mobile units (including aircraft), needed for threat and general modelling of the electronic environment.

j. Any other data, such as photographs or reports from tourists, agents etc.

All these need incorporating into a common, correlated digital data base source. This should be coordinated with USAF project 2851.

Project 2851 participants to note

DATA AND CUES NEEDED TO ACHIEVE THE TRAINING TASK

20. US Army Programme. It was stated that the US army (ARI Fort Rucker) had a programme called SCTB (Simulation Complexity Test Bed) using a CT6 IG, in order to establish the minimum criteria and optimum criteria for helicopter training. Resolution, polygons, modelling, texture etc. were being assessed.

21. Fast-Jet Study Programmes. There was a need for similar study programmes for fast jet training. After

discussion, the group supported the following programmes:

a. The FRG was asked to obtain data from the GAF Tornado update programme using the ESIG-1000 IG and the CAE FOHMD display system, and to produce a report. — Appropriate FRG Agency

b. The UK was asked to run a similar programme using facilities such as those at RAE and the new Harrier GR5 simulators which had the MODDIG IG and the ESPRIT display system. The FRG and UK should liaise in order to agree methodologies, and to avoid duplication of effort. — Appropriate UK Agency

c. The AGARD Flight Mechanics Panel (FMP) had proposed a working group to coordinate, stimulate and collate information from research programmes on simulator cueing for low flying. The FRG and UK programmes above should become part of this activity. It was understood that there were also activities in the Netherlands, North America and other NATO countries which could also contribute to the FMP working group. — Appropriate National Agencies

d. Several delegates pointed out that information on crew behaviour was lacking, such as where pilots look, and how they move their heads during various real tasks in the air. This was relevant to simulation techniques such as eye-and head-slaving, and to FOV required. — National Research Agencies.

22. <u>Research in Italy.</u> The Aermacchi delegate presented some vufoils on visual system characteristics. These were:

Page C-18 Classes of simulation vs fidelity
C-19 CGI delays vs task duration (helicopter)
C-20 Pilot opinion (Cooper/Harper Rating) with varying resolution and texture.
C-21 Rating improvements with FOV, resolution and texture.

The vufoils brought out the advantage of texture, resolution, FOV and reduced CGI delays, but mathematical methods applied to alter Cooper/Harper ratings were more problematical (vufoil C-21).

NATO STANDARDS FOR SIMULATION

MAIN RECOMMENDATION (NATO standards for simulation)

23. It was noted that there were no NATO Standards for Simulation, whereas in the civil sector there were positive criteria for different standards of simulator, such as the US FAA Phase 1, 2 and 3 requirements. It was proposed that NATO standards for military simulation should be formulated, as guidelines for both customer nations and contractors. In the longer term, it was suggested that combat readiness credits might be gained in simulators capable of tasks not possible in the aircraft such as war route training, full EW scenarios, release of own and enemy weapons, mission rehearsal etc.

MOTION CUEING

24. An extensive discussion took place on the various types of motion cueing, and the SL's vufoil on the subject is at page C-22, C-23. The points already minuted at para 9 were reiterated and showed that, in an aircraft, the motion (acceleration) cues were felt first followed by the visual (displacement) cues, and so in a simulator it was acknowledged as essential that this sequence was preserved with the motion platform reacting at the same time as, or slightly before, the visual system. The other way round, as had happened in some simulators, was known to produce adverse cueing, as did excessive platform time delays or latencies. Regarding the use of hydraulic motion platforms, it was agreed that:

a. Poorly set-up motion platforms produced worse cueing than having no motion platform. This showed the power of motion cues, and the need for them to be properly presented to the pilot.

b. There were examples of older simulators still in Service, where pilots had lost faith in the cueing produced by the motion platform and had asked for it to be switched off.

c. It was agreed that the current generation of platforms developed primarily for the civil market, had greatly improved characteristics compared to older designs. Modern synergistic platforms with smoothly operating hydrostatic jacks, had latencies approaching 120 msec. When well set-up for the aircraft and role, it was agreed that modern platforms were very beneficial to realistic training and to the use of real aircraft control and stability models in the simulator. — Nations to note

d. It was likely that if well set-up motion platforms were not used the simulator became less realistic in terms of handling qualities. — Nations to note

e. Research was needed on the optimisation of current industry-standard motion platform drive laws for the fast-jet role. This should be part of the FRG, UK and other studies covered in para 21. — FRG, UK and other research agencies.

25. For fighter aircraft, the target response time to control inputs was quoted as 100 msec (US MIL STD F 87 85C).It was suggested that this should therefore be the target latency for military simulator motion platforms. The visual system response should then shortly follow, after the motion. Industry confirmed that a 100 msec platform latency was a practical target. — Industry to improve platform latencies and achieve 100 msec.

26. <u>Cueing for G-forces.</u> It was recognised that the most significant cueing deficiency for fighter simulators would probably be the lack of ability to

produce forces on the body similar to the G-forces in an aircraft.

a. Use of Anti G-Suits in Simulators. The UK pointed out that the pressure in the pilot's Anti G-suit was a very strong cue in a fighter simulator in the absence of real body forces, but that a rapid response of G-suit pressure to computed G was needed so that the pilot had rapid feedback from his stick movements. It was suggested that the range of computed G over which a simulator G-suit produced changes of pressure, might be increased compared to the range used in aircraft, to give some G-cueing at higher computed G; a graph was shown to the delegates and is reproduced at page C-24.

b. G-Seats. The use of G-seats in simulators with a variety of functions to supplement cueing for G, can complement other cues. Simple cues such as 'seat-of-the-pants' pressure were said to be very effective.

c. Further Research. It was agreed that further research was required into the best way to improve simulator cueing for Normal G. This should include the relative merits of motion platforms, Anti G-suits, simulator G-seats (both simple and more complex), and visual cueing such as effects of tunnel vision, grey-out and black-out. The FRG, UK and other studies mentioned in para 21 should address this.

FRG, UK and other research agencies.

27. Instrument Flying (IF). With a well set-up modern 6-DOF platform it was suggested that realistic Instrument Flying (IF) training could be carried out in the simulator, in the same way that the higher standards of airline simulators were used for this purpose. There was therefore the possibility of off-loading military aircraft from some routine IF training, allowing more emphasis to be placed on combat-related flying.

Nations to note.

28. USN and USAF views on Motion Platforms. It was noted in discussion that the USN and USAF did not appear to support the use of motion platforms for fast-jet simulators. Various delegates pointed out that this was at least partially due to experiments on earlier build-standards of platforms with performance that would not match current standards (older platforms had, amongst other characteristics, high latencies, in some cases up to 300 msec had been quoted, well into the area where adverse effects would be experienced in a fighter simulator). In was understood that at two research agencies, NTSC (Orlando) and USAF HRL (Williams AFB, Phoenix), there were no examples of modern motion platforms. However it was noted that the US Army used motion platforms extensively, there being about 45 platforms at Fort Rucker alone, including many modern 6-DOF synergistic models.

29. Simulator Sickness. It was stated that there was evidence that wide FOV visual systems which had rich scene detail, when operated without stimulating the pilot's vestibular senses (the inner ear semi-circular canals and the otolith), produced a trend to simulator sickness due to a cue mismatch compared to flying a real aircraft. This could be exhibited as a feeling of disorientation, unreality, the 'leans' or nausea. It was also stated that the use of a well set-up modern motion platform greatly reduced this trend by enabling the trainee to sense similar vestibular sensations to those experienced in the aircraft, which should then be shortly followed by changes in the visual scene.

Nations to note.

30. Motion Platforms - Cost. On 25 Oct, a preliminary discussion took place with the Operational Group of the Workshop, at which a summary of the two groups' proceedings was given. The operational group asked for indications of the cost of motion platforms, and industry indicated that, in general, high quality visual were the cost drivers, motion platforms making up between 5 and 10% of the total cost of a good quality modern simulator.

Nations to note.

NEED FOR DATA

MAIN RECOMMENDATION, (as in para 2)

31. Industry noted the difficulty of obtaining data, particularly on aircraft systems (radar, IR, avionics, EW etc.). The civil ARINC 610 philosophy does not yet apply to military equipment. Often, the use of "real aircraft blackboxes" were the best solution where emulation would prove difficult. Industry suggested that ADA data might help when it was more universally used. The UK stated that some stimulation of blackboxes would always be needed, combined with some emulation of, for instance, sensors such as radar, FLIR, acoustics etc. It was also stated that there was a need for better data for good sensor modelling, which did not exist at present. A "NATO version" of ARINC 610 was also needed, as recommended in para 2, where aircraft black boxes were designed from the outset to be capable of use in the simulator without expensive modifications.

32. The complexity of modelling weapon systems for simulation was mentioned, also the difficulty of obtaining aircraft data on emergency cases such as asymmetric stores, etc. The need was also noted for battle damage models, which would have to be predicted. Also, when an incident occurred to an aircraft in service, it was important that the Flight Data Recorder data was analysed and used, not only to update the simulator data base but also for training such incidents in the simulator.

Nations, and Manufacturers of Aircraft, Simulators and Flight Recorders to note. part of the main aircraft project)

33. Data Packs for Simulation. It was stated that the civil aircraft world was much better in providing good data for flight simulation. An example given recently at a Royal Aeronautical Society Simulation Symposium in London, was that Boeing flew 35 extra hours on the 747-400 for simulator parameters alone. As a result of this policy, Boeing produced excellent data packs for simulation manufacturers, a feature noticeably lacking from most military equipment suppliers. It was recommended that the data required for simulation should be part of the main aircraft programme, because later when the simulators were being built was often too late. Data for low level operations was recognised as a particular requirement. Additionally, it was stated that there were no military standards (the equivalent of FAA, IATA, standards etc.) to which such data should conform. It is therefore recommended that such NATO data standards for simulation should be formulated.

MAIN RECOMMENDATION (Good data packs for simulation to be ordered as part of the main aircraft project)

34. Threat Modelling. Industry stated that, for good threat modelling, they needed more threat data such as 6 DOF data for air threats. Interactive multiple real time threats were said to be currently limited by computing capacity. For mission simulation, SAM and AAA threats also had to be modelled. Out-of-visual-range threats would not be registered on the visual system and needed a further, longer range data base. There was a need for powerful systems for sortie initialisation and management. Industry pointed out the need for user-friendly threat modelling aids for rapid reaction to intelligence and reconnaissance data for mission rehearsal tasks. Forthcoming 'expert systems' should help the instructor in creating realistic threat scenarios which were not repetitive.

MAIN RECOMMENDATION (NATO standards for simulator data)

LINKING OR NETWORKING SIMULATORS

35. The importance of linking or networking simulators together was recognised. This was straightforward between simulators at the same site, and there were several networks of this nature working in the USA - up to eight aircraft simulators being linked, and over 40 tank simulators in the US Army 'Simnet' programme. Areas of technical concern in networking were as follows:

a. There was a need for a NATO data interface standard to be applied to all procurements where linking of simulators may be required. This was needed to make networking possible between simulators built by different manufacturers.

MAIN RECOMMENDATION (NATO network interface standard)

b. A study was required on the type and capability of network links themselves. The interaction between data rates, transfer time delays and bandwidth should be studied and related to a variety of training tasks. Particularly, could combat tasks requiring rapid interactive manoeuvring, be accomplished over long range network links?

MAIN RECOMMENDATION (Study on capabilities of network links)

c. System management and instructor requirements needed to be taken into account. This emphasised the need for backfeed of data. This should be part of the study called for in (b) above.

COMBINED MEETING OF THE OPERATIONAL AND TECHNICAL GROUPS

36. The Operational and Technical groups then met in combined session. The Operational group listed a number of Operational Requirements for simulation which were then considered for feasibility and limitations, and summarised in a matrix table which is also attached to the proceedings of the workshop.

See the attached table of Operational Requirements and Simulator Characteristics.

5. Table of Operational Requirements for Simulation compared with Simulation capabilities

5. AGARD WORKSHOP ON LOW LEVEL FLYING AND FLIGHT SIMULATION
TABLE OF OPERATIONAL REQUIREMENTS
COMPARED TO SIMULATION CAPABILITIES

Chairman: Rolf Behrmann, FRG (IABG)
Secretaries: Rolf Lautenschlager, FRG (IABG)
Ian Strachan, UK (MOD, RAF)

OPERATIONAL REQUIREMENT FOR SIMULATION	TECHNICAL FEASIBILITY OF SIMULATION	LIMITATIONS OF SIMULATION	REMARKS
1. Exact replication of aircraft cockpits.	Feasible	Nil	There is the need for some real aircraft equipment, because cockpit equipment such as HUDs and some displays, cannot be cost-effectively emulated (ie produced synthetically without using real aircraft hardware). The need for such real aircraft equipment for simulators must be allowed for in the main aircraft programme, or the simulator manufacturer will find it very difficult to obtain.
2. Crew's own aircrew equipment capable of being used in the Simulator, including NBC kit, NVGs etc.	Feasible	Eye-slaved systems currently require a simulator-specific helmet, with the addition of a small oculometer above one eye which tracks the angle of look.	Some display systems are not compatible with the use of real NVGs in the simulator, and have to emulate the NVG picture. The simulator is a safe environment to train using full NBC kit including the face mask.

3. Simulation of all systems.	Feasible	Data is needed for sensor modelling and for emulation of systems.	Data on some aircraft systems (Weapons, EW,aircraft etc) is sometimes difficult to obtain by simulator manufacturers. Need for customer to specify to his main equipmentmanufacturers that the data required forsimulation is to be prepared, and provided to the simulator manufacturer at the appropriate time.
			'Real World' data for sensors needs improvement. See serial 19.
		In addition to emulation, some real aircraft 'black boxes' will normally have to be used.	Aircraft 'black boxes' for military aircraft are not currently designed for use in simulators, and are often not compatible with use in simulators without modifications. Civil aircraft equipment designed to ARINC 610 is compatible with direct use in simulators. A NATO equivalent to ARINC 610 is needed.
			Simulator manufacturers often find great difficulty in obtaining necessary aircraft hardware due to the higher priority normally given to hardware for aircraft by the equipment supply agencies. Note 2 to the Remarks at Serial 1 applies.
		Simulators ares difficult to keep in step with aircraft mod state.	Future simulators must be kept in step with aircraft, and sets of modified hardware needed for simulators must be provisioned by the equipment supply agencies at the same time as the aircraft. There is the possibility of using simulators to prove new software programmes for aircraft.

4. Accurate simulation of:			
a. Aircraft performance.	Feasible	Nil	Straightforward, given the data.
b. Handling Qualities.	Feasible	Accurate data on control and stability is a problem	Validated flight test data and good visual and motion cues are required in order to achieve handling fidelity. The Technical group recommended the use of a modern motion platform, and a visual system giving a total FOV of at least 140 x 70 , if realistic handling was required.
		Simulation of normal G (Gz) has severe limitations.	To give G-cueing despite the lack of real Gz cues, the pilot's Anti-G suit, a simulator G-seat, and the use of visual system effects at high computed G (tunnel vision, grey-out, black-out) are needed, all carefully adjusted to give optimum indication of computed G to the pilot.
5. Simulation of Air-to-Air and Air-to-Ground threats.	Feasible	Data governs realism, and level of interaction with threats drives cost.	Large numbers of 6-DOF models in the scenario need large computing power. The requirement for A/A threat has an impact in the visual system 360° projection, different resolution and contrast levels.
		Realistic size of small objects at long ranges (eg Air-to-Air targets) has limitations. See Remarks.	Small visual objects at long range may have to be enhanced in size and/or shape in the simulator in order to achieve 'real world' acquisition and detection ranges, unless special target projectors are used. See Serials 17 and 18 on 'resolution'.
			At higher simulated altitudes, more emitters have to be modelled.

6. Realistic Electronic Warfare Simulation (ECM, ESM etc)	Feasible	Data governs realism.	Provision of good data sometimes difficult, even on own systems. Simulator manufacturers need access to data in order to produce good simulation. Note 1 to the Remarks to Serial 3 applies.
7. Simulation of flares, chaff and endgame manoeuvring.	Feasible	Nil	Nil
8. Simulation of Airspace Management (C2, mission planning etc).	Feasible	Nil	Nil
9. Simulator potential for expansion - new threat scenarios, new weapons, aircraft changes etc.	Feasible	Nil	Capability for change should be designed in at the start. Functions that might need adjustment, need to be programmable through software rather than being fixed in hardware. Modular design helps, also the use of a powerful, use-friendly DBWS.
10. Simulation of 2-ship and 4-ship formation, simulators at same location. (ESSENTIAL REQUIREMENT for tactical training).	Feasible	Cost drives fidelity of simulation.	For full interactive training, separate simulators are required for each aircraft in the formation. In the USA an interactive 8-simulator system exists for aircraft, and the US Army 'SIMNET' system networks over 40 tank simulators.
		Availability of aircrew to man all the elements of the simulation may be a problem.	More limited training can be obtained by operating a single simulator with the leader or other ships in the formation represented by computer models which could also be controlled from the IOS.

			Other simulations appropriate to the role should be considered for the network. For instance, AD aircraft operating at lower levels to be included in Ground Attack simulation networks, also attack helicopter simulators where relevant to the scenario. In the AD role, include AWACS, Tanker aircraft and AD control simulations as well as the fighter aircraft simulators.
11. Networking of simulators at different locations in order to increase the number of participants in the simulation (Desirable future aim rather than present firm requirement).	Feasible as long as data rates for the simulation are compatible with capacity of the network links.	High data rates for rapid changes in interactive scenarios may cause difficulties over long range network links.	Scenario management needs backfeed of data - the networking needed is therefore a two way link at a variety of data flows. Study required on networking for interactive scenarios. Data flow, reaction times, security of information, and costs etc for various tasks. NATO protocol required for standard simulator interfaces to future network links, so that simulators for different types from different manufacturers can be compatible with working together.
12. Calculation of realistic weapon characteristics and trajectories in simulators.	Feasible	Need for accurate weapon system data.	Simulator manufacturers find accurate data sometimes difficult to obtain. Help from customer is often required to obtain data. Note 1 to the Remarks to Serial 3 applies.
13. Weapon accuracy calculations available in simulator (eg Circular Error Probable (CEP), miss distances, hit/Pk probabilities, etc).	Feasible	Nil	Need for data on weapon trajectory, weapon effect, and dudding/misfires. Given agreed data, it is straightforward for the simulator computer to compute weapon effects. Weapon accuracies and effects can be varied to match the training scenario (eg all hits, fixed proportion of hits, hits base on a random number programme, etc).

14. Munitions:			
Normal Operation.	Feasible	Need for data.	The aircraft flight test programme should take into account the need for simulator data, although on safety grounds the more extreme malfunctions will not be flight tested. Simple malfunctions such as hang-ups, misfires and dudding are straightforward. However, flight data recorder information on any later in-flight incidents should be used to update the simulator data base.
Malfunctions.	Feasible	Data has to be estimated for the more extreme cases that cannot be flight tested.	
15. Munitions - generation of fragmentation and warhead lethality envelopes in the simulator, own and enemy weapons, on intended targets and other aircraft (such as other aircraft in a formation).	Feasible	Nil	Warhead fragmentation data is part of the weapons clearance process. Straightforward to use such data in simulator. Enemy weapon data has to be estimated. Blast and turbulence effects can be simulated through motion platforms and G-seats. Battle damage can be simulated to various levels, using assumptions agreed with the customer on the effects of such damage (eg loss of fuel, systems, control & stability effects etc).
16. Visual weapon effects, own and others, friends and enemy.	Feasible	Simulation of several simultaneous weapon effects may exceed the capacity of some visual systems.	Flight path of weapon, warhead detonation, and effect on target can be modelled, including weapon dudding. Visual effects needed, include changes to weapons on pylons as weapons are released, for both ownship and others in visual range.
17. Simulator visual systems to achieve same resolution as the human eye (About 1 arc minute per Optical Line Pair, as in AGARD AR 159).	Feasible over small areas only	Up to about 7 circular area with current CGI systems.	Can be target-slaved (eg use of specific target projectors, laser projectors being capable of giving better resolution than the eye). Optimum resolution only achieved at high contrast ratios.

	NOT FEASIBLE over larger areas	Yes, see Remarks column.	Current Computer Generated Visual (CGI) systems have best resolutions of about 3 - 5 arc minutes per Optical Line Pair (OLP), depending on the area over which an optical channel is projected. Area-of-Interest (AOI) channels used with eye-slaved systems use about 16 -20 circular, whereas about 7 would be needed to achieve 1 arc min/OLP. The higher figures are chosen so that the blending with the background scene on the outer of the AOI is not visually obtrusive. See Serial 18 for impact on target acquisition and recognition.
18. Target acquisition and recognition in the simulator at similar ranges to the real world.			
a. Area Target	Feasible	Nil	Visual scenes are stylised but adequate for recognition.

b. Point Target	See Limitations in next column. MISSION CRITICAL	Small targets at long ranges subtending the same angle to the pilot as in the aircraft, will not be seen on current raster-scanned CGI systems (see serial above). Such targets can, however, be enhanced in size and shape at long ranges so that the required acquisition and recognition ranges may be achieved, as long as this does not produce confusing effects to the trainee.	The FRG and UK evaluations on visual and other cueing should address this crucial point. Other conditions such as time of day/night, visibility, cloud, E-O sensors etc must be considered. CGI systems already schedule the size and shape of cultural features on the terrain in a series of steps as the feature comes closer, unobtrusive to the pilot ('level of detail' control) and so similar adjustments to targets may be found to be acceptable.
19. Simulation of sensors such as Radar and FLIR to be:			
a. Realistic	NOT FEASIBLE over large areas	Better radar and IR data from the real world required for realism of modelling over large areas. Present systems use predicted data with some stylisation of imagery.	Need for NATO data acquisition programme. Sensor modelling is part of the FRG and UK evaluations. Simulation hardware exists (eg radar and IR processors), but large-area real world data does not.

b. Accurately with other systems such as visual and EW data bases.	NOT FEASIBLE over large areas. MISSION CRITICAL.	Data does not exist on which to base correlation on, over large areas. Labour-intensive modelling necessary at present to achieve result.	Need for NATO data base to include visual andcorrelated all sensor information, accurately correlated and in a format for ease of use.
20. Realistic Terrain and Cultural Features used in low flying to be available on simulator visual system.	Real-world Realism - NOT FEASIBLE	Computer-Generated scenes are stylised. Fidelity limited by polygon and texture capability of the CGI system, and by the real-world data available for modelling.	Some CGI systems accept DLMS for automatic transformation into visual scenes. DLMS Level 2 (30 metre grid spacing of height points) is required for reasonable fidelity, but is not available yet for some areas of Western Europe. For more refined height points, and more sophisticated cultural feature data, better than DMLS level 2 is required. Currently this is achieved by laborious manual modelling. Digital mapping systems of the future must take simulation and mission planning into account.
a. Time-of-the-year changes in the visual scene to be represented, particularly where they affect flying techniques or sensor responses.	Real-world Realism - NOT FEASIBLE	Present systems generate snow scenes by changing terrain colour to whites and shades of grey. Colours of fields and trees can be changed using a DBWS, but need further data base storage, such as on a separate disc or discs.	More development needed for future CGI systems to match the military need, both in realistic terrain and cultural features and also in correlation with sensor data which is affected by changes in terrain condition (eg snow, rain effects on radar, IR etc). Will be part of the FRG and UK studies.

		No automatic correlation with changes to sensor data bases in snow, rain, loss of leaves in Autumn, etc.	
21. Ability to contour simulator	Feasible	More DLMS Level 2 DTED data required for better accuracy of terrain.	Digital Terrain Elevation Data (DTED) is fromfly in the a 100m grid in DLMS Level 1 which is generally available. The Level 2 (30 m grid) is not available over many areas and is needed for better representation of terrain. General contour flying at high speed and low level based on Level 1 data has been demonstrated in several simulators, including in rugged terrain. Edges of polygons can be visually smoothed by appropriate shading (visual blending).
22. Full range of aircraft speeds available in the simulator.	Feasible	Very high speeds require higher screen refresh rates.	Future systems will be more capable due to improvements in computing.
		Systems optimised for lower speeds may show some 'feature popping' at medium ranges at very high speeds.	As above. Feature 'popping' is where cultural features suddenly appear in the middle distance because system overload management denies their appearance at longer ranges. Depends on density of scene detail, and ownship groundspeed.
23. Weather effects relevant to low flying available in the simulator.	Full weather effects: NOT FEASIBLE	Present systems do not model broken cloud layers, or small variations of cloud base. When above cloud, modelling of holes in the cloud with realistic terrain below, is difficult with some systems.	Next generation of systems are addressing these aspects.

	Some weather effects:	Effects other than the above are modelled in current systems.	Visibility changes are straightforward. Cloudbase changes are generally in steps. Effects such as rain, sleet, snow, thunder and lightning, with the associated turbulence up to microburst intensities, are well modelled because of the civil requirement.
24. Simulation of emergencies including battle damage.	Feasible	Accuracy of data governs realism	See Note 3 in the Remarks to Serial 15 on Battle Damage. See Note 1 in the Remarks to Serial 14 on flight test and other data.
25. Simulator Sortie Management. a. Minimise need for involvement of front-line aircrew.	Feasible	Use of pre-recorded lesson plans will need careful preparation.	Sortie monitoring and management at the Instructor Operating Station (IOS) can be by non-front line aircrew. However, important simulator tactical sorties will need front line specialists for assessment and debrief.
b. IOS facilities to manage complex tactical scenarios.	Feasible	Design must not allow pilots to become used to set scenarios.	Networking with other simulations, or random number programmes to govern interactions within a scenario, will prevent repetitive training (where repetition is not needed to make a teaching point). Powerful IOSs already exist. Some make use of Graphics computers and VDUs (Megatek, Silicon Graphics etc) to allow setting up, monitoring and recording of complex scenarios, sensors and visual scenes. Enhancement of tactical features possible at the IOS, when needed.

c. Briefing and Debriefing facilities for full exploitation of tactical elements of sortie.	Feasible	Nil	The use of Graphics computers and VDUs allow debriefing aids such as viewing scenes from other eye-points. Such as the view from an opponent's cockpit, or the view from a SAM or AAA site to illustrate skylining above the horizon. Replay can be in real time, fast or slow, or freeze.
(1) To include the facility to replay elements of the sortie in the simulator itself.	Feasible	Next sortie cannot start if simulator is in use for debrief.	Separate Debrief Facility will be more versatile and is not time-limited.
		If visual or motion cues are played back in anything except 'real time', disorientation or 'simulator sickness' can result.	Simulator visual cues are very powerful with a Wide-FOV system, and if used for debrief, should be used with great care.
Motion System	Feasible		It will increase the riding fidelity especially in small manoeuver tasks. It is effecting pilots acceptance.

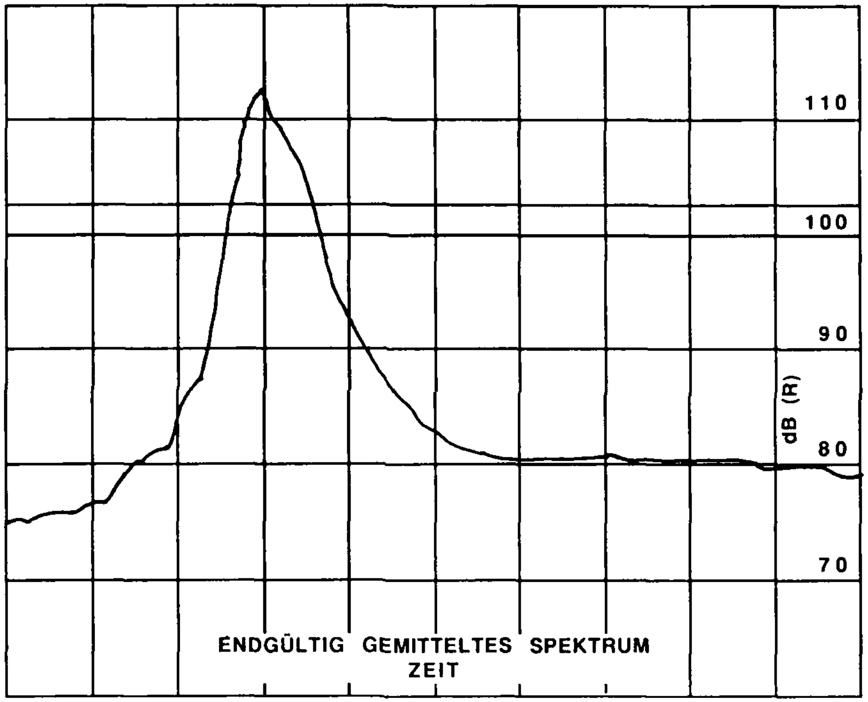
5.1 Critical Areas for Improvement for Low Level Training

This is a summary of the critical areas indicated in Column 2 of the table of Operational Requirements compared to currend simulation capabilities.

REF IN TABLE	SERIAL NO.	CRITICAL AREA TO BE IMPROVED	REMARKS
17	1.	Simulator visual systems cannot achieve a similar resolution to that of the human eye (about 1 arc minute per Optical Line Pair) except over a small Field-of-View (about 7°)	Targets slaving can be used. See also Serial 2 no Resolution
18	2.	Acquisition and detection of point targets is not possible at realisitc ranges if targets are at 'real world' sizes, in simulators using Computer Generated Imagery for general scene information as well as for the targets.	Target slaving with special projectors can be used, also enhancement in size or shape of targets at longer ranges.
19 a	3.	Real-world data on sensor imagery is not available over large geographic areas.	NATO sensor imagery data base needed.
19 b	4.	Accurate data with which to correlate sensor, terrain and visual data bases, is not available over large geographic areas.	NATO data base needed with all data correlated
20	5.	Realistic terrein and cultural features are not available on even the most capable CGI systems (Visual scenes are stylised).	Fidelity of systems is being improved. Photographic texture techniques improve fidelity over small areas.
20 a	6.	Time-of-the-year changes are not realistically modelled, either in the visual IR or radar data base Correlation needed of changes such as due to snow, leaf fall in autumn, colour changes in crop patterns, IR changes in rain etc.	Needs work, both on visual data bases and sensor response changes with season and weather.
23 a	7.	Full weather effects for a low flying environment are not available (eg broken cloud effects, precise settings for cloudbase overhills, wind effects in hills, etc.)	Weather effects are being improved in future systems.

INTRODUCTION

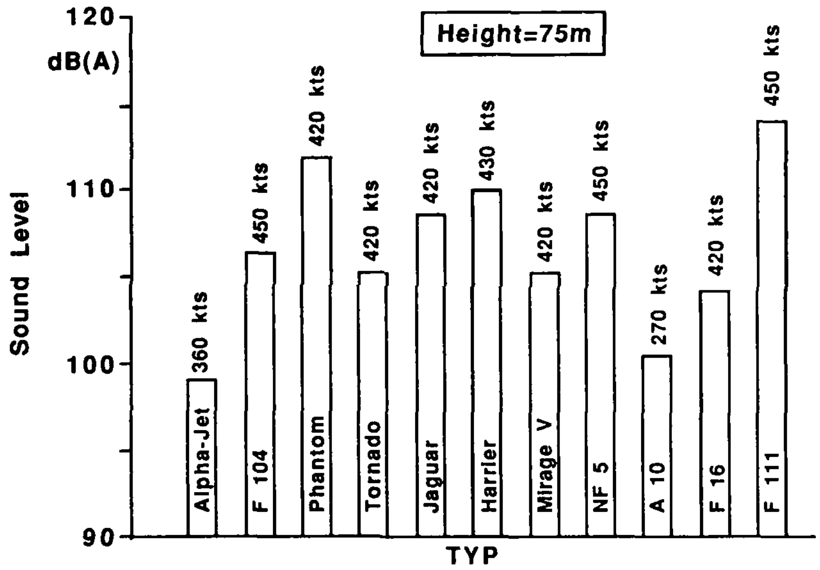
NOISE LEVEL TIME HISTORY



TIME HISTORY OF A F 4 PHANTOM OVERFLIGHT (SPEED 420 KTS, HEIGHT 75 m, CENTER MICROPHONE)

INTRODUCTION

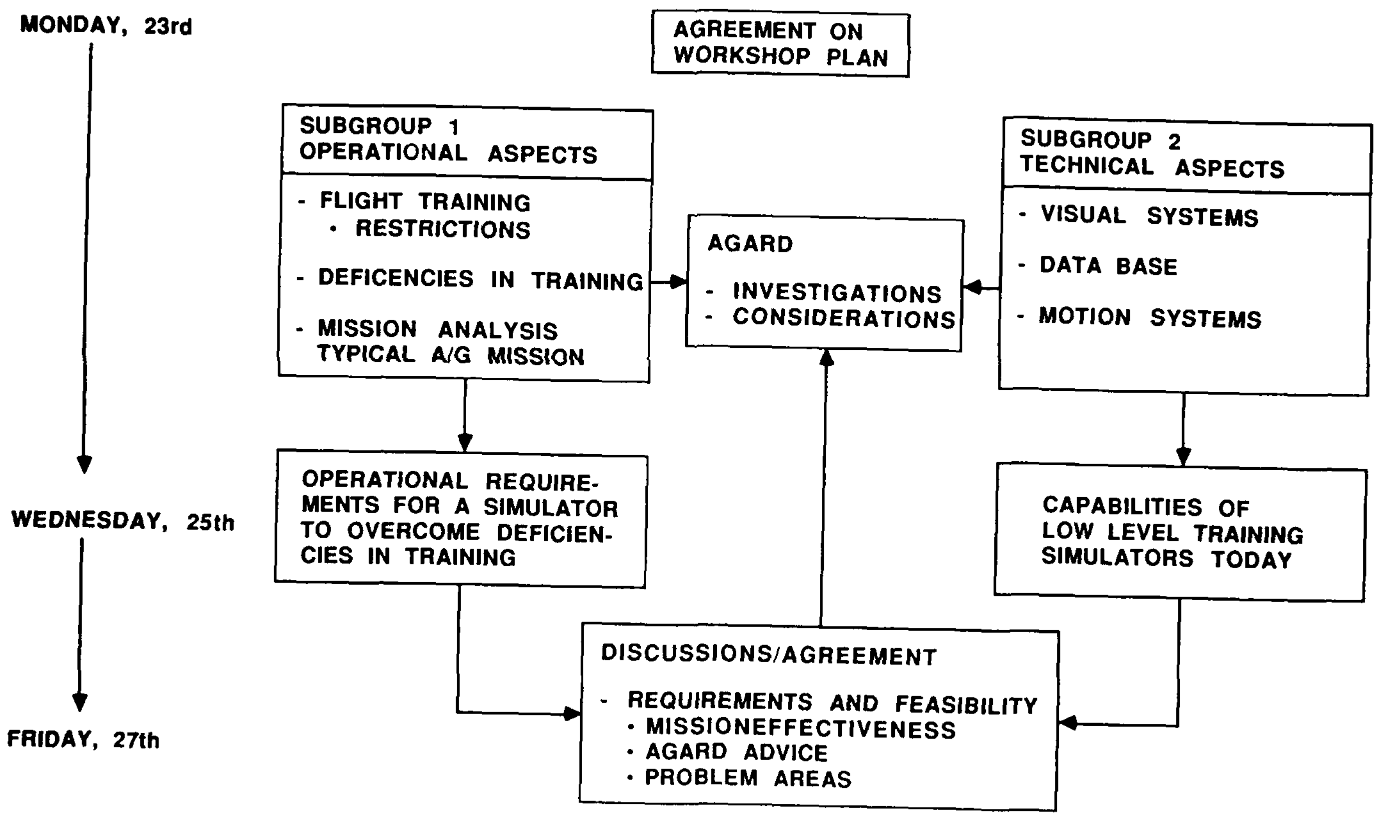
NOISE LEVELS OF DIFFERENT AIRCRAFT TYPES



NOISE LEVELS FOR ALL MEASURED AIRCRAFT TYPES
(HEIGHT 75 m, SPEED AS INDICATED, CENTER MICROPHONE)

AGENDA:

PRESENTATION: LOW LEVEL FLIGHT TRAINING OF THE GERMAN AIR FORCE
B. GEN. H. MERKEL

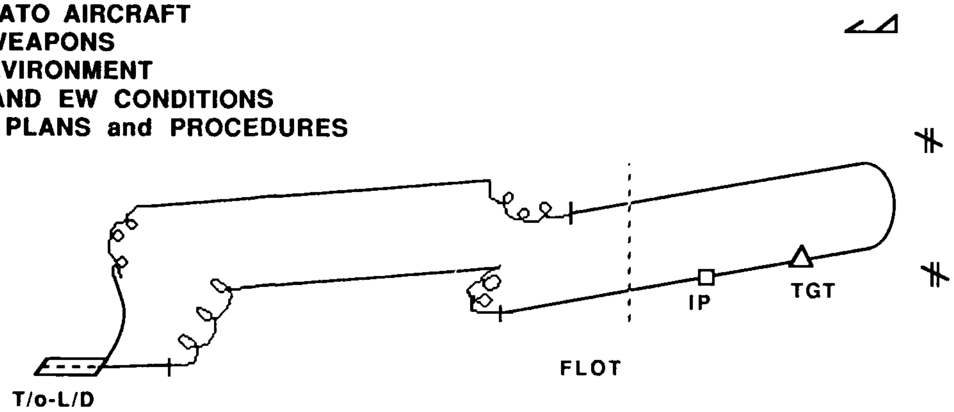


OPERATIONAL ASPECTS TO REDUCE TRAINING DEFICIENCIES

MISSION ANALYSIS (TYPICAL AIR TO GROUND MISSION)

- CURRENT WEATHER (DAY AND NIGHT)
- REALISTIC THREAT (A/A and A/G)
- REAL COMBAT TERRAIN
- TACTICAL FORMATION
- ALL NATO AIRCRAFT
- ALL WEAPONS
- C_2 ENVIRONMENT
- NBC AND EW CONDITIONS
- NATO PLANS and PROCEDURES

- WEAPON DELIVERY
- IP TO TGT AQUISITION
- INGRESS / EGRESS
- TRANSITION
- T/c, DEPARTURE
- APPROACH / LANDING
- GND OPERATION



- BE ABLE TO PERFORM ALL TACTICAL CONSIDERATIONS AND TASKS IN THE SIMULATOR

TECHNICAL ASPECTS — POINTS OF DISCUSSION

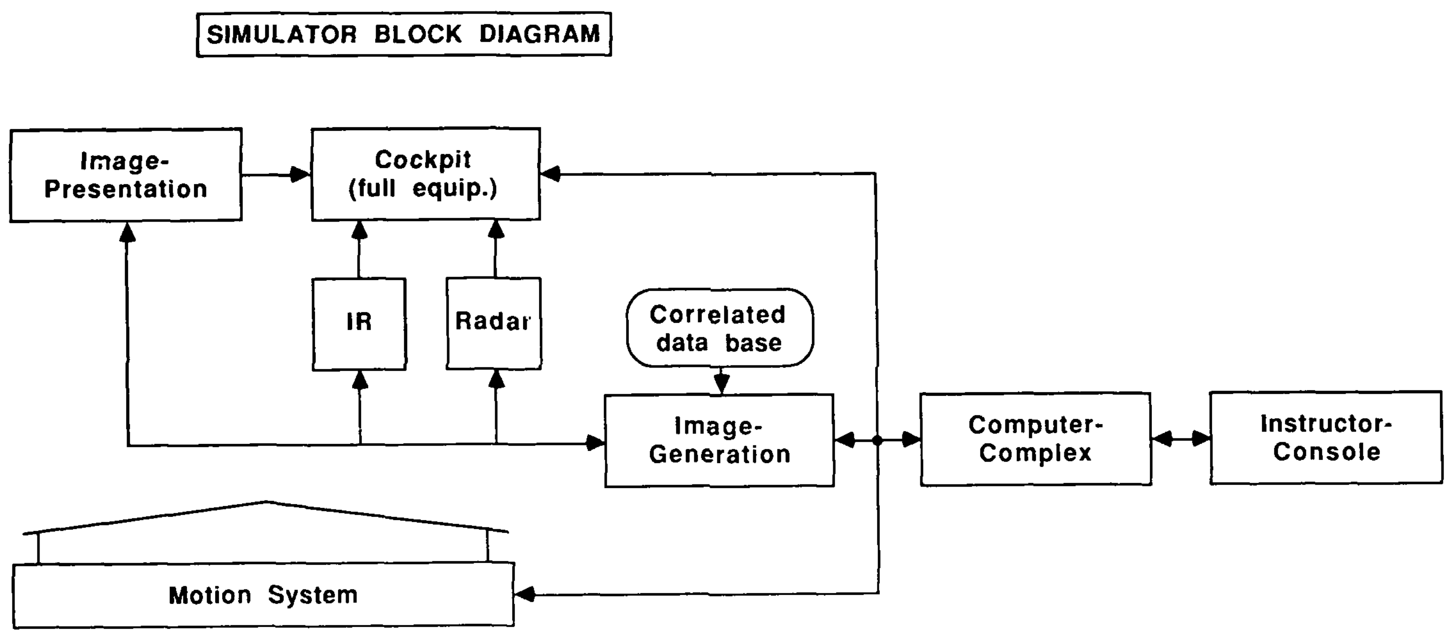
TOPICS	PARAS
Modelling	1, 2, 31-34
Aircraft, Avionic, EW-systems, Threat	
Visual systems (hardware)	
• Image presentation	4-7
FOV, Resolution, Brightness, Contrasts	
WFOV- and AOI-systems	
• Image generation	8-17
scene content, min CGI	
scene dynamics, AOI-support	
radar- and FLIR-simulation	
Data bases	(15), 18, 19
source data collation, correlation	
mission rehearsal, weather effects	
Motion systems	20-30
motion perception,	
motion systems, motion sickness	
Networking	
interface problem	
Standardization (NATO)	2, 19, 23, 31, 33, 35
standards for simulators	
standards for HIL (like ARINC 610)	
standards for data packages	
standards for data bases (2851)	

TECHNICAL ASPECTS

MODELLING

<u>AIRCRAFT</u>	• ACCURATE DATA NEEDED, FLIGHT TEST DERIVED → FEW DATA AVAILABLE FOR EMERGENCY CASES (OUT OF FLIGHT ENVELOPPES)
<u>AVIONIC / EW-SYSTEMS</u>	• STRUCTURAL MODELS AND DATA MOSTLY NOT AVAILABLE → USE OF ORIGINAL EQUIPMENT (HARDWARE-IN THE-LOOP) → BUT NATO-STANDARD FOR ARINC 610 NOT ESTABLISHED
<u>THREAT</u>	• BETTER DATA ON AIR THREATS SAM THREATS AAM THREATS NEEDED • EXPERT SYSTEMS MIGHT HELP MODELLING THE THREAT SCENARIOS

TECHNICAL ASPECTS



TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE PRESENTATION

REQUIREMENTS

FOV	MIN. 140° x 70°	→ DEPENDS ON MANOEUVRING TASKS
RESOLUTION	MIN. 4 ARCMIN / OLP	→ DEPENDS ON DETECTION, RECOGNITION AND IDENTIFCATION TASKS
BRIGHTNESS	MIN. 6 FTL	
CONTRAST	6:1	

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE PRESENTATION

SOLUTIONS FOR WFOV SYSTEMS

- REAL IMAGE SYSTEMS: MOSAIKED DOMES → MANY CHANNELS, EXPENS., DIM
- VIRTUAL IMAGE SYSTEMS: MULTIVIEWER MIRROR SYSTEMS → LIMITED IN VERTICAL FOV
- AREA OF INTEREST SYSTEMS: AT PRESENT 2 PROTOTYPES
  - ESPRIT:
    UK, HARRIER GK5
    REAL IMAGE DOM SYSTEM
    FIXED BACKGROUND 340° x 140°, 22′/OLP
    HEAD/EYE-SLAVED A0I 18° CIRC, 3′/OLP
    BRIGHTNESS 1,3-5 FTL
    CONTRAST 6:1
  - FOHMD:
    FRG, TORNADO
    VIRTUAL IMAGE SYSTEM
    HEAD-SLAVED BACKGROUND 127° x 67°, 12′/OLP
    FIXED AOI 25° x 19°, 3,8′/OLP
    BRIGHTNESS : 6-10 FTL
    CONTRAST : 30:1
  - PROBLEMS:
    ACCEPTANCE OF MODIFIED HELMETS
    ACCURACY OF EYETRACKERS AND AOI-PROJECTORS
    CALIBRATION PROCEDURE
    USE IN CREW-COCKPITS

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE GENERATION

REQUIRED SCENE CONTENT

OPTICAL FLOW: ALL SCENE ELEMENTS STREAM OUTWARD FROM AN AIMPOINT IN FRONT OF THE AIRCRAFT

→ HIGH SPATIAL FREQUENCIES IN THE SCENE
→ ALL KINDS OR TEXTURE NEEDED

O. F. USED FOR ESTIMATES OF:
- HEIGHT
- GROUND SPEED
- RANGE
- ATTITUDE
- ALTITUDE CHANGE
- FICTIONS POINT AT IMPACT
- CLOSURE RATE

FOVEAL INFO: 3D-OBJECTS WITH FAMILIAR SIZE AND KNOWN FEATURES

→ LOW SPATIAL FREQUENCIES, HIGH DETAILLED OBJECTS
→ MUCH POLYGONS FOR MODELLING + ALL KINDS OF TEXTURE

F.I. USED FOR IDENTIFICATION OF NAVIGATIONAL POINTS
IDENTIFICATION OF TARGETS (SIZE AND SIZE CHANGE)

→ KNOWN VERTICAL CUES + OPTICAL FLOW PROVIDES PARALLAX CUES AND INFORMATION ABOUT SIZE SCALE OF OBJECTS

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE GENERATION HARDWARE

MINIMUM REQUIREMENTS FOR A CGI - SYSTEM QUALIFIED FOR LL-TRAINING

SYSTEMPARAMETERS

CHANNEL	UP TO 8
COORD. SYST.	>10
RESOLUTION	512 K... 1000 K PIXEL / CHANNEL
EYEPOINTS	> 4

SCENE QUANTITY

POT. VIS. POLYG.	> 1000/CHANNEL
LOD	≥ 8
OVERLOAD CAP.	NON IMAGE DISTRACTING

SCENE QUALITY

ANTIALIASING	
TEXTURING	MODULATION, CONTOUR, MACRO, FOTO, GEO
SHADING	
COLOR	
TRANSLUCENCY	

SCENE DYNAMICS

UPDATE RATE	≥ 50 HZ
REFRESH RATE	≥ 50 HZ
DELAY TIME	< 80 MS

SPECIAL

- WEATHER
- DIST. CORRECTION
- AOI-SUPPORT
- IR-SENSORS } POSTPROCESSOR
- RADAR } POSTPROCESSOR

DATA BASE DEVELOPMENT

- USER-FRIENDLY WORKSTATION
- HIGHLY AUTOMATIC TOOLS

MAINTENANCE

- BOARD LEVEL DIAGNOSTICS
- FEW BOARDTYPES

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE GENERATION HARDWARE

SCENE DYNAMICS

REFRESH RATE :

- HIGH ENOUGH TO AVOID FLICKER
  (FLICKER FREQUENCY DEPENDS ON BRIGHTNESS AND CONTRAST RATIO:
  DOMES (3 FTL) → 50 HZ SUFFICIENT
  VIRTUAL DISPLAYS (10 FTL) → ≥ 60 HZ REQUIRED)
- PROGRAMMABLE REFRESH RATES MAY HELP FOR ONLINE EXPERIMENTS

UPDATE RATE :

- LOW LEVEL SCENES DEMAND FOR HIGH IMAGE SPEEDS
  → UPDATE RATE AS HIGH AS POSSIBLE ≥ 60 HZ
  BUT CONSISTENT WITH REFRESH RATE TO AVOID MULTIPLE IMAGES
- PROGRAMMABLE UPDATE RATES MAY HELP FOR ONLINE EXPERIMENTS

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE GENERATION HARDWARE

REQUIRED AOI-SUPPORT:

- ADAPTION OF RECTANGULAR IMAGE FORMAT TO OTHER FOV-SHAPES (CIRCLES, ELLIPSES) WITHOUT PIXEL LOSS (PIXEL COMPRESSION)
- LOD CONTROL IN THE BLENDING REGION BACKGROUND → INSET
- SPEED OF CGI-SYSTEMS WITH RESPECT TO HEAD MOVEMENTS
- SUPPORT FOR EYE TRACKED SYSTEMS

  A) COLLIMATED IMAGES:

  - HEAD MOTION COMPENSATION OF RELATIVE POSITION OF SCENE ELEMENTS
  - EYE POSITION INFORMATION TO COMPUTE RELATIVE DISPLACEMENT OF SCENE ELEMENTS

  B) REAL IMAGES (DOMES):

  - LARGE OFF-AXIS PROJECTION REQUIRES ONLINE NON LINEAR DISTORTION CORRECTION

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE GENERATION HARDWARE

WEATHER EFFECTS

IMPORTANT WEATHER EFFECTS, (CAUSES PILOT REACTIONS):

BROKEN CLOUD LAYERS (FINE STEPPED)
THUNDERSTORM CLOUDS
CLOUDS-CLUSTERS
FOGGY AREAS (IN VALLEYS)
WIND AND TURBULENCE IN HILLS

PRESENT LIMITATIONS:

- NO DETAILLED DESCRIPTION OF TYPICAL EUROPEAN WEATHER CLUSTERS AVAILABLE
- NO MATHEMATICAL 3D-MODELS FOR WEATHER CLUSTERS AVAILABLE
- CORRELATION PROBLEM WITH DIFFERENT SENSORS
- CGI-SYSTEMS NOT WELL SUITED FOR GENERATING W.E.

→ POLYGON CAPACITY PROBLEMS
→ WILL BE SO VED BY INTRODUCTION OF NEXT GENERATION CGI (1990/91)

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE GENERATION HARDWARE

RADAR SIMULATION

TASK: GENERATION OF A MONOCHROME RASTER IMAGE WITH ALL RADAR-RELATED FEATURES AND DEFICIENCIES USING THE COMMON CORRELATED DATA BASE

REQUIREMENTS

MODES : GROUND MAP RADAR (REAL BEAM, SAR)
TERRAIN FOLLOWING
AIR TO AIR

RESOLUTION : REAL BEAM $\leq$ 100 FT
SAR 10 FT
DISPLAY 512 x 512 PIXEL

SCANFORMATS: CIRCULAR PPI (2 - 3 IM/S)
RECT. RASTER (50-100 LINES/S)
SAR (1 IM/2-3 S)

QUALITY : TREND TO HIGH RESOLUTION IMAGES
→ REAL RADAR QUALITY SATURATES CGI-CHANNEL CAPACITY

EFFECTS: REFLECTIVITY
DIRECTIVITY
FAR SHORE BRIGHTENING
BEAMSPREAD
SHADOWING
RANGE ATTENUATION
MOVING OBJECT DISPLACEMENT } (SAR)
TALL OBJECT DISPLACEMENT } (SAR)
WEATHER EFFECTS
TEXTURE
JAMMING EFFECTS

TECHNICAL ASPECTS

VISUAL SYSTEMS: IMAGE GENERATION HARDWARE

FLIR SIMULATION

TASK: GENERATION OF A MONOCHROME RASTER IMAGE WITH ALL IR-RELATED DEFICIENCIES USING THE COMMON CORRELATED DATA BASE

REQUIREMENTS:

- SEPERATE EYEPOINT FOR THE SENSOR
- MONOCHROMATIC SCENE FROM 1 CGI-CHANNEL
- POSTPROCESSOR FOR SEVERAL IMAGE TRANSFORMATIONS
  - o OPTICS (RESOLUTION, FOV, INTENSITY DISTR.)
  - o SCANNER (ACCURACY, JITTER)
  - o SENSOR ARRAY (MIN. RESOLVABLE TEMP. DIFFERENCE)
    SPECTRAL RESPONSE
    NUMBER OF LINES
    HORIZONTAL RESOLUTION
    (TEMPORAL RESPONSE)
    BLACK STRIPES
  - o AMPLIFIER (NOISE, GAIN CONTROL MAPPING
    60DB TO 256 STEPS)
  - o SCAN CONVERSION
    (RASTER GENERATION FOR CRT)

TECHNICAL ASPECTS

DATA BASES: SOURCES

DMA DLMS (ORIGINALLY DEVELOPED FOR RADAR SIMULATION)

DTED (DIG. TERRAIN ELEVATION DATA):

- LEVEL 1 : SAMPLE POINTS DISTANCE 100 m (WORLD WIDE AVAILABLE)
- LEVEL 2 : SAMPLE POINTS DISTANCE 30 m (SPECIAL AREAS)
- ACCURACY : ±50 TO ±130 m HORIZONTALLY
  ±16 TO ±120 m VERTICALLY

DFAD (DIG. FEATURE ANALYSIS DATA):

DESCRIPTION OF CULTURAL FEATURES OF EARTH SURFACE

- LEVEL 1 : GENERALIZED DESCR. OF PLANIMETRIC FEATURES (2-DIM. FOOTPRINTS)
  MIN. SIZE REQUIREMENTS
- LEVEL 2 : DETAILLED DESCR. WITH SMALLER SIZE REQUIREMENT

DFAD FEATURES: POINTS, LINEAR, AREA (100 m)
GEOGRAPHIC POSITION
IDENTIFICATION CODE
MATERIAL CATEGORIES
HEIGHT
SPECIAL

- GROUP 1: TERRAIN SURFACE FEATURES (NO 3-D-INFO)
- GROUP 2: DESCRIPTION OF 3-D-OBJECTS ONLY WITH FOOTPRINTS AND PREDOMINANT HEIGHT (NO REAL 3-D-MODELLING)

SATELLITE STEREO IMAGES: SPOT

- FORMAT : 60 km x 60 km
- RESO-LUTION : 10 m MONOCHROME
  20 m MULTISPECTRAL

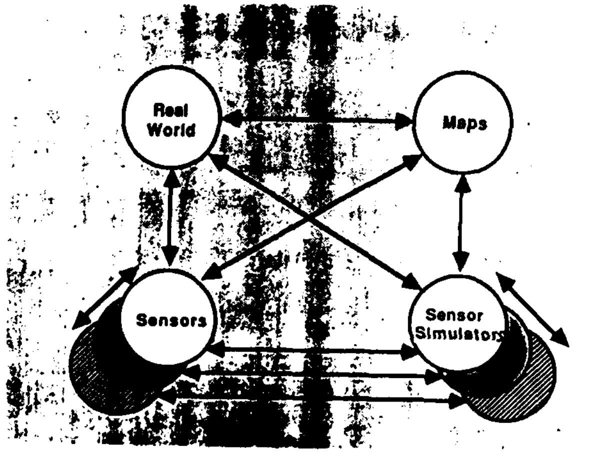
AFTER RADIAMETRIC CORRECTION, GEOMETRIC CORRECTION AND ORTHOGANALIZIATION: STEREO INTERPRETATION ELEVATION DATA FOR GEOTEXTURE AND OBJECTS (±10 m)

AREAL IMAGES: RESOLUTION <1m
SUPPLEMENT OF OTHER DATA SOURCES FOR SPECIAL HIGH DENSE AREAS

TECHNICAL ASPECTS

DATA BASES: CORRELATION

CORRELATION :	STRUCTURAL FUNCTIONAL QUALITATIVE	CORRESPONDENCE BETWEEN TWO CORRELATABLE ENTITIES
ENTITIES :	REAL WORLD MAPS SENSORS (VISUAL, RADAR, FLIR, LLTV...) SENSOR SIMULATION	



TECHNICAL ASPECTS

DATA BASES: CORRELATABLE CHARACTERISTICS

BETWEEN DIFFERENT ENTITIES

- TERRAIN FIDELITY
- FEATURE CORRELATION

<u>INTERFEATURE</u>

FEATURE DENSITIES
INCLUSION / EXCLUSION CRITERIA
PLANIMETRIC ACCURACIES

<u>INTRAFEATURE</u>

TYPE OF FEATURE
POSITION DATA
PHYSICAL DIMENSIONS
SENSOR ATTRIBUTS
(MATERIAL TYPE
EMISSIVITY
REFLECTIVITY ETC.)

→ SIMULTANEOUS CORRELATION FOR ALL ENTITIES AND ALL CHARACTERISTICS IS NOT ACHIEVABLE

→ <u>USER MUST PRIORITIZE</u> THE CORRELATION CHARACTERISTICS

→ <u>PREREQUISITE:</u> GENERATION OF A COMMON <u>IMAGE LIBRARY</u> CONTAINING ENOUGH SPECTRAL RELEVANT DATA FOR EITHER ANSWER AND EITHER CHOICE

TECHNICAL ASPECTS

DATA BASES: REQUIREMENTS FOR MISSION REHEARSAL

DEFINITION USE OF ACCURATE, CORRELATED DATA BASE TO SIMULATE A MISSION EXACTLY AS IT WILL BE EXECUTED

REQUIREMENTS

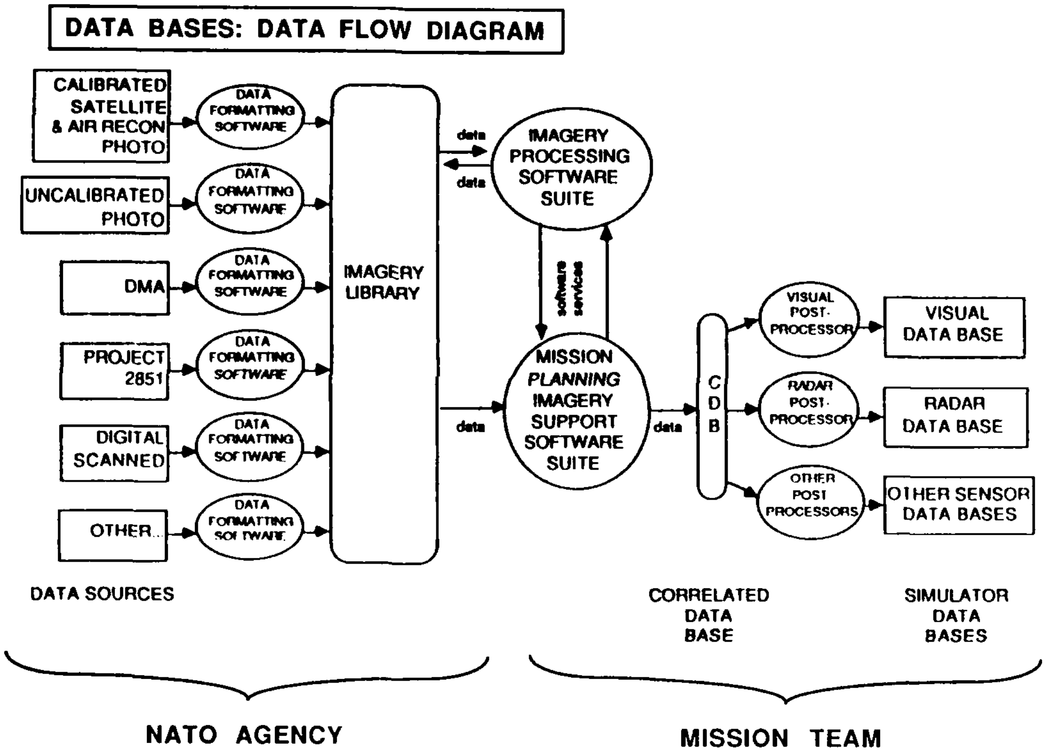
- o ACCURATE DATA BASE CONTAINING
  - MISSION ROUTES AND TARGETS AT SUFFICIENT RESOLUTION
  - CORRELATED IR AND RADAR FEATURES OF MISSION ROUTE AND TARGETS → STOCK OF VISUAL, IR AND RADAR DATA (TERRAIN AND FEATURES) → GENERATION OF AN IMAGE LIBRARY CONTAINING DATA FROM DIFFERENT SOURCES

  PROBLEMS: DIFFERENT RESOLUTION AND ABSOLUTE ACCURACIES
  DIFFERENT SPECTRAL RANGES
  DIFFERENT COLLECTION TIMES
  FEATURE MOVEMENT
  DIFFERENT SENSORS } CAUSES INCONSISTENCY
  → HIGHLY INTERACTIVE PROCESS!

- o MISSION TEAM SHOULD BE ABLE FOR QUICK PRODUCTION OF THE SPECIAL MISSION DATA BASES

  → USERFRIENDLY INTERFACE
  CONTEXT-SENSITIVE HELP SYSTEM WITH TUTORIAL ERROR RECOVERIES
  HIGHLY AUTOMATIC TO GET SHORT TIMES

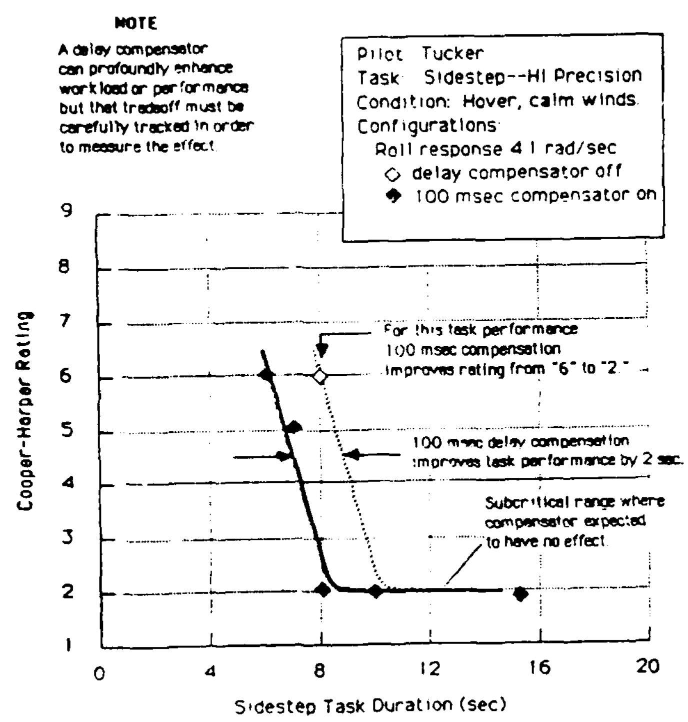
TECHNICAL ASPECTS



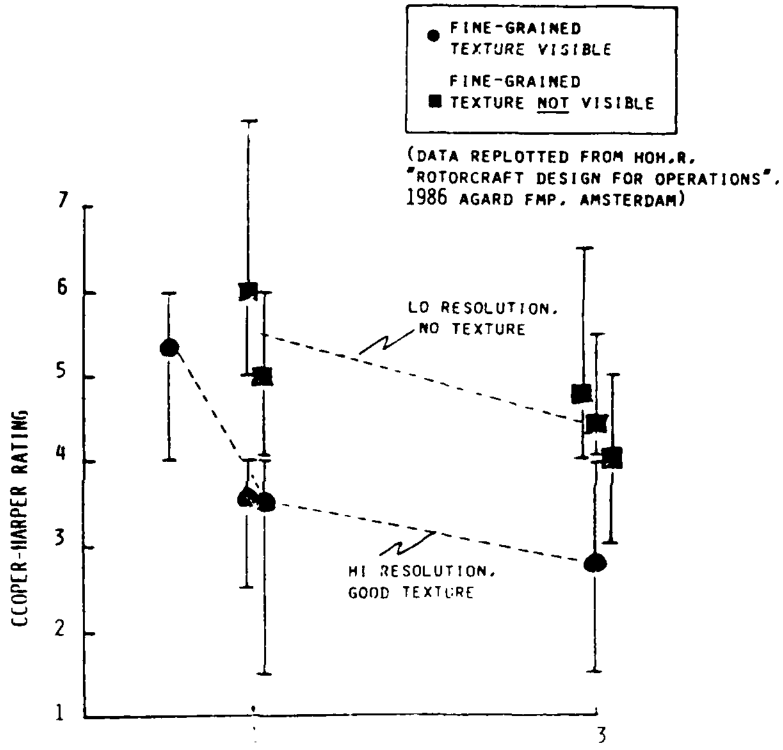
CLASSES OF ENGINEERING SIMULATION

& FIDELITY FACTOR REQUIREMENTS

CLASS	DESCRIPTION	PURPOSE	A/C MODEL	MOTION	TASKS
I	**Pre-First Flight Evaluation of New Aircraft**	• Control Law Design • Flying Qualities • Stability & Control • Failure Modes & Effects • Esploration of Flight Envelope • Test Pilot Training	• Non Linear Model • 6 Deg-of-Freedom • Highly Rigorous	Yes	• First Flight Safety • Take-off & Landing • Academics • Tracking Tasks • Validate Flight Test Plan
II	**Flight Control/ Integrated Controls Development**	• Flying Qualities • Gain/Phase Margins • Ride qualities • Integrated Controls	• 6 Deg-of-Freedom • Broad Bandwidth	Yes	• Mission Modes • Tracking Tasks • Academics
III	**Crew Station Design**	• Cockpit Development • Human Factors • Workload • Switchology • Display Formats • Controllers • Air Traffic Controls • Mission Planning • Voice Controls	• Linear Mdeol • Detailed Cockpit		• Part-Task • Visual/Sensor Correlation • Workload Assesment Tasks
IV	**Total Mission**	• Man Machine Integration • Mission Management • Workload Assesment • Levels of Automation • Threats	• Medium Rigor • Detailed Cockpit • Weapons Guidance • EW/ECM		• Full Contiunuos Mission scenario • Visual/Sensor Correlation • Targets Tracking • Weapons Delivery


NOTE
A delay compensator can profoundly enhance work load or performance but that tradeoff must be carefully tracked in order to measure the effect.
Pilot Tucker
Task: Sidestep--HI Precision
Condition: Hover, calm winds.
Configurations:
Roll response 4.1 rad/sec
delay compensator off
100 msec compensator on
For this task performance 100 msec compensation improves rating from "6" to "2."
100 msec delay compensation improves task performance by 2 sec.
Subcritical range where compensator expected to have no effect
Cooper-Harper Rating
Sidestep Task Duration (sec)
1
2
3
4
5
6
7
8
9
0
4
8
12
16
20

GENERAL EFFECT OF TEXTURE, RESOLUTION, AND FIELD OF VIEW ON PILOT OPINION



NOTE :
- HIGH RESOLUTION AND GOOD TEXTURE CAN IMPROVE RATINGS BY ABOUT 1 1/2 CHR PTS
- WIDE FIELD OF VIEW CAN IMPROVE RATINGS BY ABOUT 3/4 CHR PT

PERFORMANCE INDEX ESTIMATION

RATING-POTENTIAL IMPROVEMENT AS.

- **horizontal field of view increases**

$$horiz\Delta = \frac{FOV_H - 40^\circ}{160^\circ - 40^\circ} \times 1\ CHR$$

(e.g., +0.5 CHR for 120° FOV)

- **vertical field of view increases**

$$vert\Delta = \frac{FOV_V - 25^\circ}{50^\circ - 25^\circ} \times 1\ CHR$$

(e.g., +1.4 CHR for 60° FOV)

- **resolution increases**

$$res\Delta = \frac{\ln(4\ arcmin) - \ln(RES)}{\ln(2)} \times 1.5\ CHR$$

(e.g., +1.5 CHR for 2 arcmin resolution)

- **texture improves**

$$text\Delta = TEXT \times 0.5\ CHR$$

TEXT = 0 - no texture (early CGIs)
25 - horizontal texture (e.g., SP-[illegible])
50 - 3-d texture (e.g., SP-X)
75 - cell texture (e.g., COMPUSCENE-IV)
1 - real world

$$index = horiz\Delta + vert\Delta + res\Delta + text\Delta$$

TECHNICAL ASPECTS

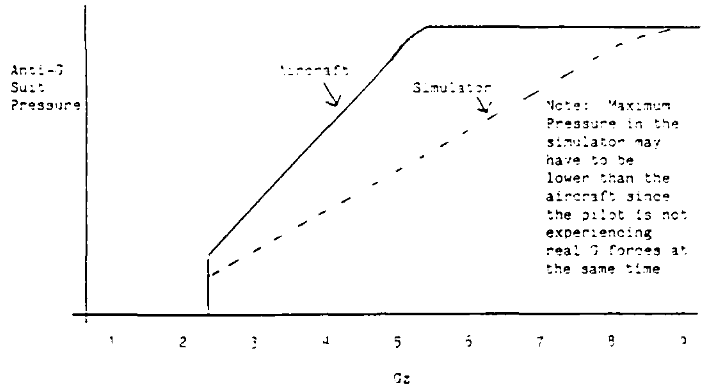
MOTION: SENSORS FOR MOTION PERCEPTION

VESTIBULAR SYSTEM	SEMICIRCULAR CANALS AND OTHOLITS → TRANSLATIONAL AND ROTATIONAL ACCELERATIONS 0,1 HZ OR RATES (0,1 - 10 HZ)
SOMATOSENSORY SYSTEM	TACTILE AND PRESSURE SENSORS → ATTITUDE OF BODY (INERTIAL ORIENTATION)
KINESTHETIC SYSTEM	→ RELATIVE POSITIONS OF POINTS OF THE BODY AND BODY ACCELERATIONS
VISUAL SYSTEM	PERIPHERAL RETINA → MOTION DETECTION, VECTION

TECHNICAL ASPECTS

MOTION: TECHNICAL SYSTEMS

6 DOF PLATFORM (SYNERGISTIC):	DIRECT STIMULATION OF THE VESTIBULAR SYSTEM NEEDS A FAIR AMOUNT OF EXCURSIONS STIMULATION OF THE SOMATOSENSORY SYSTEM INDIRECT
G-SEATS:	DIRECT STIMULATION OF THE SOMATOSENSORY SYSTEM; *PROVIDES ONSET CUES FOR VECTION IN WFOV-VISUAL SYSTEMS*
ANTI G-SUIT:	DIRECT STIMULATION OF THE SOMATOSENSORY SYSTEM; PROVIDES CUES FOR SUSTAINED G-FORCES; LIMITED RANGE FOR 2.5 TO 6G
PROBLEMS:	• LIMITS: SUSTAINED REAL G'S NOT AVAILABLE • DRIVE LOGIC: QUALITY OF WASHOUT ALGORITHMS INFLUENCES THE FIDELTY OF MOTION • SYNCHRONIZATION: MOTION AND VISUAL CUES MUST BE SYNCHRONIZED IN SUCH A WAY, THAT - TOTAL DELAY TIME IS LESS 100 ms - MOTION CUE PRECEDES VISUAL CUES BY A SMALL AMOUNT OF TIME



DIAGRAM

The drive law should be under software control so that it can be easily adjusted for maximum effectiveness during acceptance testing. It is important that the simulator G suit pressure has a low lag with respect to synthetic G. In aircraft, this lag is of little importance but in simulators I have flown with high G-suit pressure lags, the value of the cue is highly degraded and you can even have the situation where you have reversed G to negative and yet still have positive pressure in the G-suit. This is a significant false cue and must be avoided. Finally, research should be carried out on whether it may be beneficial to have a slight positive G-suit pressure at 1G in the simulator, so that small changes to this can be used to embrace G-cueing in the region between main G-suit pressure onset and down to the negative G regime. However since this cue is not present in the aircraft, results may show that this technique does not help or even is counter-productive. It may also be possible to have a more elaborate G-suit in the simulator, covering more body area, in an effort to enhance G-cueing.

G-SEATS

Specially modified seats can be used in simulators to enhance various motion cues. The simplest is probably the Cranfield design which incorporates, for increase in simulated G, buttock pressure through a movable pad in the seat, and seat-pan lowering. It is also capable of strap tighting under negative G, simulating being thrown against the straps. The movable seat pad is a highly effective cue, particularly for the lower G values before G-suit onset, and the seat pan lowering is also a useful cue to complement the higher G suit pressures at higher G. It is, however, important that any lags in operation of the seat pad in response to 'aircraft' pitch and heave motions, are minimal, since the seat pad movement is giving the 'seat of the pants' cue to the pilot.

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's Reference	3. Further Reference	4. Security Classification of Document
	AGARD-AR-288	ISBN 92-835-0572-7	UNCLASSIFIED

5. Originator Advisory Group for Aerospace Research and Development
North Atlantic Treaty Organization
7 rue Ancelle, 92200 Neuilly sur Seine, France

6. Title WORKSHOP ON LOW LEVEL FLIGHT TRAINING

7. Presented at IABG, Ottobrunn, Federal Republic of Germany, 23rd—27th October 1989.

8. Author(s)/Editor(s)	9. Date
Various	June 1990

10. Author's/Editor's Address	11. Pages
Various	80

12. Distribution Statement This document is distributed in accordance with AGARD policies and regulations, which are outlined on the Outside Back Covers of all AGARD publications.

13. Keywords/Descriptors

Altitude	Effectiveness
Flight simulators	Combat readiness
Operational flying training	

14. Abstract

The workshop investigates and reports on whether flight simulation technology might help resolve problems associated with low level flight training and suggests how AGARD might proceed in this area. Specifically the workshop:

— Registers the existing requirements for low level flight training for mission events in which flight simulator technology shows the greatest potential for reducing the environmental impact of flight training while maintaining combat readiness.

— Identifies ways that simulator technology can be applied to reduce the undesirable impact of low level flight training.

— Investigates new training concepts that use alternative flight training in connection with simulators to meet flight training requirements.

— Identifies ways to measure the effectiveness of simulator training in meeting operational training requirements.

— Suggests possible topics for follow-on technology studies or aerospace applications studies through which AGARD might contribute to a solution to the issue.

AGARD Advisory Report No.288
Advisory Group for Aerospace Research and Development, NATO
WORKSHOP ON LOW LEVEL FLIGHT TRAINING
Published June 1990
80 pages

The workshop investigates and reports on whether flight simulation technology might help resolve problems associated with low level flight training and suggests how AGARD might proceed in this area. Specifically the workshop:

— Registers the existing requirements for low level flight training for mission events in which flight simulator technology shows the greatest potential for reducing the

P.T.O.

AGARD-AR-288

Altitude
Flight simulators
Operational flying training
Effectiveness
Combat readiness

AGARD Advisory Report No.288
Advisory Group for Aerospace Research and Development, NATO
WORKSHOP ON LOW LEVEL FLIGHT TRAINING
Published June 1990
80 pages

The workshop investigates and reports on whether flight simulation technology might help resolve problems associated with low level flight training and suggests how AGARD might proceed in this area. Specifically the workshop:

— Registers the existing requirements for low level flight training for mission events in which flight simulator technology shows the greatest potential for reducing the

P.T.O.

AGARD-AR-288

Altitude
Flight simulators
Operational flying training
Effectiveness
Combat readiness

AGARD Advisory Report No.288
Advisory Group for Aerospace Research and Development, NATO
WORKSHOP ON LOW LEVEL FLIGHT TRAINING
Published June 1990
80 pages

The workshop investigates and reports on whether flight simulation technology might help resolve problems associated with low level flight training and suggests how AGARD might proceed in this area. Specifically the workshop:

— Registers the existing requirements for low level flight training for mission events in which flight simulator technology shows the greatest potential for reducing the

P.T.O.

AGARD-AR-288

Altitude
Flight simulators
Operational flying training
Effectiveness
Combat readiness

AGARD Advisory Report No.288
Advisory Group for Aerospace Research and Development, NATO
WORKSHOP ON LOW LEVEL FLIGHT TRAINING
Published June 1990
80 pages

The workshop investigates and reports on whether flight simulation technology might help resolve problems associated with low level flight training and suggests how AGARD might proceed in this area. Specifically the workshop:

— Registers the existing requirements for low level flight training for mission events in which flight simulator technology shows the greatest potential for reducing the

P.T.O.

AGARD-AR-288

Altitude
Flight simulators
Operational flying training
Effectiveness
Combat readiness

environmental impact of flight training while maintaining combat readiness.

— Identifies ways that simulator technology can be applied to reduce the undesirable impact of low level flight training.

— Investigates new training concepts that use alternative flight training in connection with simulators to meet flight training requirements.

— Identifies ways to measure the effectiveness of simulator training in meeting operational training requirements.

— Suggests possible topics for follow-on technology studies or aerospace applications studies through which AGARD might contribute to a solution to the issue.

ISBN 92-835-0572-7

environmental impact of flight training while maintaining combat readiness.

— Identifies ways that simulator technology can be applied to reduce the undesirable impact of low level flight training.

— Investigates new training concepts that use alternative flight training in connection with simulators to meet flight training requirements.

— Identifies ways to measure the effectiveness of simulator training in meeting operational training requirements.

— Suggests possible topics for follow-on technology studies or aerospace applications studies through which AGARD might contribute to a solution to the issue.

ISBN 92-835-0572-7

environmental impact of flight training while maintaining combat readiness.

— Identifies ways that simulator technology can be applied to reduce the undesirable impact of low level flight training.

— Investigates new training concepts that use alternative flight training in connection with simulators to meet flight training requirements.

— Identifies ways to measure the effectiveness of simulator training in meeting operational training requirements.

— Suggests possible topics for follow-on technology studies or aerospace applications studies through which AGARD might contribute to a solution to the issue.

ISBN 92-835-0572-7

environmental impact of flight training while maintaining combat readiness.

— Identifies ways that simulator technology can be applied to reduce the undesirable impact of low level flight training.

— Investigates new training concepts that use alternative flight training in connection with simulators to meet flight training requirements.

— Identifies ways to measure the effectiveness of simulator training in meeting operational training requirements.

— Suggests possible topics for follow-on technology studies or aerospace applications studies through which AGARD might contribute to a solution to the issue.

ISBN 92-835-0572-7